FOURTH EDITION

AMERICAN MACHINISTS' HANDBOOK

AMERICAN MACHINISTS' HANDBOOK

American Machinists' Handbook

AND

DICTIONARY OF SHOP TERMS

A REFERENCE BOOK OF MACHINE SHOP AND DRAWING ROOM DATA, METHODS AND DEFINITIONS

BY

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PREFACE TO FOURTH EDITION

In preparing the material for this, the Fourth Edition, the problem of keeping the book from becoming too bulky for convenient use has been more difficult than ever. The many new standards and practices that have come into use since the last edition, and that require much space, have added to the task. As many of these have replaced old tables, it has been possible to give much new material without adding materially to the total number of pages.

These new tables show the very latest shop practices that provide standard tolerances for screw threads for fits of various kinds and for gages with which they are inspected. They represent a great forward step in accurate machine work and eliminate many opportunities for misunderstanding. They should be carefully studied by all interested in good workmanship and in modern manufacturing.

But while the size of the Handbook has not been materially increased and much of the old book remains, it has all been carefully revised, and there is so much new material which was not formerly available that it is a new edition in every sense of the word.

We have been greatly aided in the past by friendly criticism and helpful suggestions from users of the Handbook and we sincerely trust these may be continued in the future.

THE AUTHORS.

June, 1926.

PREFACE TO THIRD EDITION

EACH revision becomes harder because of our desire to keep the number of pages down so as to avoid making a bulky book. This means a careful consideration of pages that may be omitted to make room for newer and more convenient data. For though this edition totals but seventy-seven pages more than the last, much more new material than this has been added in several important sections.

Users of the Handbook have continued their kindness in suggesting changes and additions to the contents. These are all appreciated and they will, we trust, continue as before.

THE AUTHORS.

March, 1920.

PREFACE TO SECOND EDITION

Ever since the first printing of this book, the authors have been studying ways and means of making it better, and the addition of one hundred and sixty pages by no means gives an adequate idea of the extent to which it has been revised.

Each section has been carefully studied to make it cover the changed and changing conditions of shop and drawing-room work in the hope of making it even more valuable than before.

Many of the changes have been due to suggestions made by users of the Handbook, and we shall appreciate a continuance of their interest and assistance in pointing out possibilities of improvement.

THE AUTHORS.

PREFACE TO THE FIRST EDITION

Every man engaged in mechanical work of any kind, regardless of his position in the shop or drawing room, frequently requires information that is seldom remembered and is not usually available when wanted.

With this in mind it has been our endeavor to present in convenient form such data as will be of value to practical men in the various branches of machine work. While some of the matter included may seem elementary, it was considered necessary in order to make the work complete. Much of the information has never before been available to the mechanic without tiresome search and consultation.

We believe that the Dictionary section will be found of service to the younger mechanics and in helping to establish standard names for various parts which are now more or less confused in different sections of the country.

Our indebtedness to various manufacturers and individuals is hereby acknowledged, and in the back of the book will be found a list of such authorities with page references to the information furnished by them.

We dare not hope that no errors will be found and we shall be glad to have them pointed out and to receive any suggestions as to additions or other changes which may add to the value of the book.

The Authors.

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THE AMERICAN MACHINISTS' HANDBOOK

SCREW THREADS

To avoid confusion in terms it is well to point out in the beginning the changes that have taken place in the names of what was formerly called the United States Standard thread. Originally known as the Seller's thread, it came to be abbreviated as U. S. S. where standard pitches were used, and U. S. F. (or form) where only the shape was used. This standard neither gave nor recognized tolerances and the various committees considering these, have thought best to adopt the name American (National) instead of U. S. S. As two names are unnecessary, the first name, American, has been used in this edition.

CUTTING SCREW THREADS

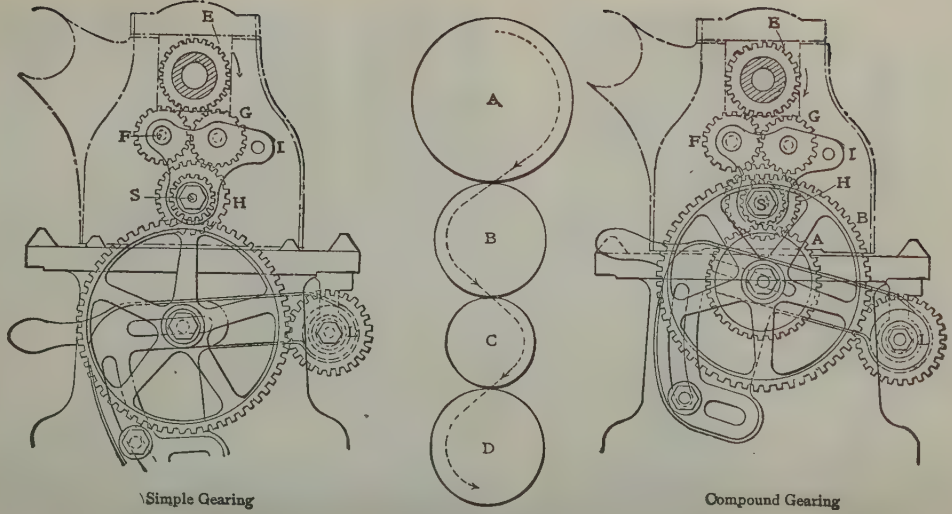
Nearly all lathes are geared so that if gears having the same number of teeth are placed on both stud and lead screw, a thread the same pitch as the lead screw, will be cut. This is called being geared "even." If the lathe will not do this, then find what thread will be cut with even gears on both stud and lead screw and consider that as the pitch of lead screw. In speaking of the pitch of lead screw it will mean the thread that will be cut with even gears.

In cutting the same thread with even gears, both the work and the lead screw are turning at the same rate. To cut a faster thread, the lead screw must turn faster than the work, so the larger gear goes on the stud and the smaller on the lead screw. To cut a slower thread (finer-pitch or less lead), the larger gear goes on the screw and the smaller on the stud.

Calling the lead screw 6 to the inch, what gears shall we use to cut an 8 thread?

Multiply both the lead screw and the thread to be cut by some number (the same number for both) that will give two gears you have in the set. If the gears vary by 4 teeth, try 4 and get 24 and 32 as the gears. If by 5, you get 30 and 40 as the gears. Then as 8 is slower than 6, the large gear goes on the lead screw and the small one on the stud.

To cut an 18 thread with a 5-pitch lead screw and gears varying by 5 teeth. $5 \times 5 = 25$ and $5 \times 18 = 90$. There may not be a 90 gear, but you can use a 2 to 1 compound gear and use a 45 gear instead. That is, put the 25 gear on the stud, use any 2 to 1 combination between this and the 45 gear on the screw.



Simple Gearing

Following Motion of a Gear Train

Compound Gearing

FIG. 1.—Lathe Gears for Screw-Cutting

The 25 gear must drive the large gear of the 2 to 1 combination and the small gear drive the 45-tooth gear, either directly or through an intermediate.

In cutting fractional threads the same rule holds good. To cut $11\frac{1}{2}$ threads with a 6-pitch lead screw and gears that change by 4 teeth, use $4 \times 6 = 24$ and $4 \times 11\frac{1}{2} = 46$, with the 24 gear on the stud and the 46 on the screw. With gears changing by 5 this is not so easy, as $5 \times 11\frac{1}{2} = 57\frac{1}{2}$, an impossible gear. Multiplying by 10 would give 60 and 115, not much better. Multiply by 6 and get $6 \times 6 = 36$ and $6 \times 11\frac{1}{2} = 69$, neither of which is in the set. Gears of 35 and 70 teeth will cut 12 threads per inch.

To find what thread any two gears will cut, multiply the pitch of lead screw and the gear which goes on it and divide this by the gear on the stud. Suppose we try 40 on the stud and 75 on the lead screw. Multiply 75 by 6 = 450 and divide by 40 which gives $11\frac{1}{4}$ as the thread that will be cut. Try 45 and 80. $6 \times 80 = 480$; divided by $45 = 10\frac{2}{3}$, showing that the 40 and 75 are nearest and that to cut it exactly a special gear will have to be added to the set. In reality, the gears would not change by 5 teeth with a 6 pitch lead screw.

Rules for screw cutting may be summed up as follows, always remembering that the pitch of the lead screw is the thread that will be cut when gears having the same number of teeth are placed on both screw and stud.

Having	To Find	Rule
A = True lead of screw and *B* = Thread to be cut	*C* = Gear for stud and *D* = Gear for screw	Multiply both *A* and *B* by any one number that will give gears in the set. Put gear *A* on stud and gear *B* on lead screw.
A = True lead of screw *B* = Thread to be cut *C* = Gear for stud	*D* = Gear for screw	Multiply *B* by *C* and divide by *A*.
A = True lead of screw *B* = Thread to be cut *D* = Gear for screw	*C* = Gear for stud	Multiply *A* by *D* and divide by *B*.
A = True lead of screw *C* = Gear for stud *D* = Gear for screw	*B* = Thread that will be cut	Multiply *A* by *D* and divide by *C*

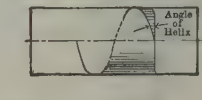
GEARS FOR SCREW-CUTTING

GEAR trains for screw-cutting are usually arranged similarly to the illustration, Fig. 1. If the gear E on the lathe spindle has the same number of teeth as the gear H on the stud S, the lathe is geared even, *i.e.*, gears having the same teeth placed on both stud and lead screw will cut a thread like the lead screw. As shown, the gears are out of mesh because the tumbler gears F and G do not mesh with E; but moving the handle I down throws F into mesh with E so the drive is through E, F, G, H, S and intermediate to L, driving it so as to cut a right-hand screw if it is a right-hand thread, as is usually the case. Raising handle I cuts out F entirely and reverses the direction of the lead screw.

To follow the motion of a train of gears, take a stick (or your finger if they are *not* running) and trace the motion from the driver to the end as shown by the dotted lines in A, B, C, and D.

When a lathe is compound geared, the stud gear drives an auxiliary gear as A, which multiplies or reduces the motion as the case may be. It will readily be seen, if the stud drives A and B drives L, the motion will be exactly doubled because A has one-half the number of teeth in B.





THREAD ANGLE TABLE

THREADS PER INCH = P

Diam. of Work	1	2	3	4	5	6	7	8	9	10	11	12
¼″	50°-14	32°-31	22°-59	17°-39	14°-18	11°-59	10°-19	9°- 2	8°- 3	7°-58	7°-11	6°- 3
5/16″	40°-23	23°- 1	15°-48	12°-16	9°-39	8°- 8	7°-13	6°-37	5°-23	5°-20	4°-49	4°-24
⅜″	32°-30	17°-41	11°-58	9°- 3	7°-16	6°-37	5°-40	4°-33	4°- 3	4°- 1	3°-37	3°- 3
7/16″	27°- 2	14°-18	9°-38	7°-15	5°-49	5°- 8	4°-10	3°-52	3°-15	3°-13	2°-54	2°-26
½″	23°- 5	12°- 1	8°- 8	6°- 4	4°-52	4°- 3	3°-52	3°- 3	2°-43	2°-26	2°-19	2°- 2
9/16″	20°- 4	10°-20	7°- 1	5°-12	4°-10	3°-28	2°-59	2°-37	2°-19	2°-18	2°- 4	1°-50
I	17°-39	9°- 2	6°- 2	4°-33	3°-39	3°- 2	2°-36	2°-17	2°- 2	2°-	1°-48	1°-31
1⅛″	15°-49	8°- 4	5°-23	4°- 4	3°-15	2°-42	2°-19	2°- 2	1°-48	1°-47	1°-37	1°-21
1¼″	14°-10	7°-12	4°-48	3°-39	2°-55	2°-26	2°- 2	1°-50	1°-44	1°-37	1°-27	1°-13
1⅜″	13°- 4	6°-37	4°-25	3°-19	2°-40	2°-13	1°-54	1°-36	1°-29	1°-28	1°-19	1°- 6
1½″	11°-59	6°- 4	4°- 3	3°- 3	2°-26	2°- 2	1°-44	1°-31	1°-21	1°-20	1°-13	1°- 1
1⅝″	11°- 6	5°-36	3°-44	2°-49	2°-15	1°-52	1°-36	1°-21	1°-15	1°-14	1°- 7	56′
1¾″	10°-26	5°-16	3°-29	2°-37	2°- 5	1°-44	1°-29	1°-18	1°-10	1°- 8	1°- 2	53′
1⅞″	9°-39	4°-52	3°-15	2°-26	1°-57	1°-37	1°-23	1°-13	1°- 5	1°- 4	58′	49′
2″	9°- 4	4°-34	3°- 3	2°-18	1°-50	1°-31	1°-18	1°- 8	1°- 1	1°- 0	54′	47′
2¼″	8°- 8	4°- 9	2°-42	2°- 2	1°-37	1°-21	1°- 8	1°- 1	54′	53′	49	41′
2½″	7°-15	3°-39	2°-26	1°-49	1°-28	1°-16	1°- 3	55′	49′	48′	43′	37′
2¾″	6°-37	3°-19	2°-13	1°-40	1°-22	1°- 7	57′	50′	45′	44′	40′	33′
3″	6°- 4	3°- 3	2°- 2	1°-31	1°-13	1°- 1	52′	46′	41′	40′	36′	30′

As most engine lathes now have quick-change gear boxes, it is nly necessary to learn the proper position of the gear change lever, r handle, for each thread or feed. This can readily be done from he plate on the lathe itself.

HELIX ANGLE OF SCREW THREADS

The helix angle of screw threads varies with both the diameter nd the lead of the screw. The larger the diameter the less the elix angle for the same lead screw. The helix angle is used in rinding thread tools and the pitch diameter should be considered nstead of the outside.

The helix angles for standard threads are given in Table I on page 39. For other diameters and leads the following formula an be used. The table below shows outside diameter angle.

Helix Angle Formula

P = single threads per inch. $\frac{1}{P}$ = lead = L

D = pitch diameter of work in inches. $\pi = 3.1416 = \frac{C}{D}$

C = pitch circumference of work in inches = πD

$$\frac{\text{Lead}}{\text{Circumference of Work}} = \frac{\frac{1}{P}}{\pi D} = \text{Tangent of Angle}$$

Find Angle in Table of Tangents

Thread Angle Table

THREADS PER INCH = P

Diam. of Work	13	14	15	16	18	20	22	24	26	28	30	32
1"	5°-36	5°-12	4°-51	4°-33	4°- 3	3°-39	3°-19	3°- 1	2°-45	2°-36	2°-25	2°-17
1⅛"	3°-45	3°-28	3°-14	3°- 3	2°-43	2°-26	2°-13	2°- 1	1°-53	1°-44	1°-37	1°-31
1¼"	2°-49	2°-36	2°-26	2°-17	2°- 2	1°-49	1°-40	1°-31	1°-24	1°-18	1°-13	1°- 8
1⅜"	2°-12	2°- 5	1°-57	1°-48	1°-37	1°-28	1°-20	1°-13	1°- 8	1°- 3	59′	54′
1½"	1°-53	1°-44	1°-37	1°-31	1°-21	1°-13	1°- 7	1°- 1	57′	53′	49′	46′
1⅝"	1°-37	1°-30	1°-24	1°-18	1°-10	1°- 3	57′	53′	49′	45′	42′	39′
1¾"	1°-24	1°-18	1°-13	1°- 8	1°- 1	55′	50′	45′	42′	39′	36′	34′
1⅞"	1°-15	1°-11	1°- 5	1°- 1	54′	49′	45′	40′	38′	35′	32′	30′
2"	1°- 7	1°- 3	50′	54′	49′	44′	40′	37′	34′	31′	29′	27′
2⅛"	1°- 1	57′	53′	50′	44′	40′	36′	33′	31′	28′	27′	25′
2¼"	56′	52′	49′	46′	40′	36′	33′	30′	28′	26′	24′	23′
2⅜"	52′	48′	45′	42′	37′	34′	31′	28′	26′	24′	23′	21′
2½"	48′	45′	42′	40′	35′	31′	28′	26′	24′	22′	21′	19′
2⅝"	45′	42′	39′	37′	33′	30′	27′	24′	23′	21′	19′	18′
2¾"	42′	40′	36′	34′	31′	27′	25′	22′	21′	19′	18′	17′
2⅞"	37′	35′	32′	30′	27′	24′	22′	20′	19′	18′	16′	15′
3"	34′	31′	29′	27′	24′	22′	20′	18′	17′	15′	14′	14′
3¼"	31′	28′	26′	25′	22′	20′	18′	17′	16′	14′	13′	13′
3½"	28′	26′	24′	23′	20′	18′	17′	15′	14′	13′	12′	11′

While the formula is worked out for single threads, it can be use for double or triple threads by considering the lead equal to th advance of the work in one revolution instead of $\frac{1}{P}$, as given in th formula.

It is customary in many shops to have several thread tools i stock to cut these various thread angles, each cutting within certain range of angles. This table will be useful in determinin the best range for each thread tool.

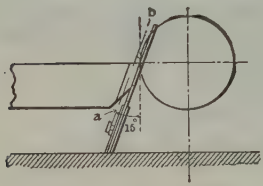


FIG. 2

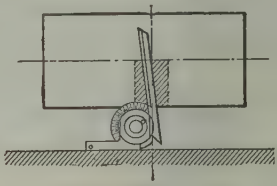


FIG. 3



FIG. 4



FIG. 5

The Use of the Protractor

Figs. 2 and 3 show side and front elevations of the thread too and of the protractor as applied to obtain the proper angle of sid clearance to cut a right-hand screw thread. The front edge of th thread tool is used to determine the angle of side clearance. Fig. shows a section taken along the line *a b*, Fig. 2. It will be notice that line *e f* is shorter than *G H* to give clearance to the cuttin edges of the thread tool, and also that *G R* is equal to *H R* and *e* is equal to *f S*. The angle of the helix at half the depth of th thread, Fig. 5, can be used, if desired, and can be approximated t from the table, or figured exactly by the method given at the to of the table.

METRIC THREADS

Metric threads are measured in millimeters but often stated b the threads per centimeter. Any lathe with a pair of compound o "translating gears" with 50 and 127 teeth, can cut metric threads

the large gear being driven from the stud. Then the gears for the number of threads per centimeter are figured the same as threads per inch as on page 3.

The gears for millimeter threads can be easily found by a simple rule. Put the 127-tooth gear on the screw. The gear for stud is found by multiplying the number of threads per inch of the lead screw by the pitch to be cut in millimeters and by 5.

EXAMPLE.—To cut 2-mm. pitch on a lathe with a lead screw having 4 threads per inch. The driving gear on the stud will be

Lead screw (4) × mm. (2) × 5 = 40, the two gears being 40 on stud and 127 on screw.

EXAMPLE.—To cut a 10-mm. thread with a 5-pitch lead screw.

Lead screw (5) × mm. (10) × 5 = 250, the gears being 250 on stud and 127 on screw.

It will frequently be necessary to compound the gears to get the desired ratio with the gears in common use.

MULTIPLE THREAD CUTTING

THE accompanying table will be found useful when cutting multiple threads. When one thread is cut, the feed nut may be opened (the spindle of course being stopped) and the carriage moved along by hand the distance given in the table; the nut is then closed on the screw and the next thread cut. This is a quick and sure method of starting the second, third or fourth thread where the lead screw of the lathe is of the pitch given in the table.

TABLE FOR MULTIPLE THREAD CUTTING

Threads per Inch	Thread Multiple	Carriage Movement	Lathe Screw Thd's per In.
$1\frac{1}{2}$–$\frac{3}{2}$	2	1″	Any
$1\frac{1}{2}$–$\frac{3}{2}$	3	Cannot be split this way.	
$1\frac{1}{2}$–$\frac{8}{2}$	4	$\frac{1}{2}$″	Any even thd.
$1\frac{3}{4}$–$\frac{7}{4}$	2	2″	Any
$1\frac{3}{4}$–$\frac{7}{4}$	3	$1\frac{1}{3}$″	6
$1\frac{3}{4}$–$\frac{7}{4}$	4	1″	Any
$2\frac{1}{4}$–$\frac{9}{4}$	2	2″	Any
$2\frac{1}{4}$–$\frac{9}{4}$	3	Cannot be split this way.	
$2\frac{1}{4}$–$\frac{9}{4}$	4	1″	Any
$2\frac{1}{2}$–$\frac{5}{2}$	2	1″	Any
$2\frac{1}{2}$–$\frac{5}{2}$	3	$\frac{2}{3}$″	3, 6, 9, 12.
$2\frac{1}{2}$–$\frac{5}{2}$	4	$\frac{1}{2}$″	Any even thd.
3 –$\frac{3}{1}$	2	$\frac{1}{2}$″	Any even thd.
3 –$\frac{3}{1}$	3	Cannot be split this way.	
3 –$\frac{3}{1}$	4	$\frac{1}{4}$″	4

To determine whether multiple thread can be spaced by carriage movement, change the threads to be cut into a common fraction. Divide the numerator by the thread multiple. If it divides evenly the thread cannot be spaced by moving the carriage. If it does not divide evenly, move the carriage the distance obtained by dividing the thread multiple into the denominator. The rule and examples given are by T. J. Lee.

The carriage can, of course, be moved 1 inch and the nut closed no matter what the pitch of the lead screw may be (unless it is fractional), but in order to close the nut after moving $\frac{1}{2}$ inch, the screw must have some even number of threads per inch.

As will be seen by referring to the table, a lead screw with any even number of threads per inch is used in a number of cases, while in several other instances the screw may be of any pitch—either odd or even. In certain cases 4 and 8 per inch lead screws are specified; and in cutting triple threads a 6 per inch screw is usual.

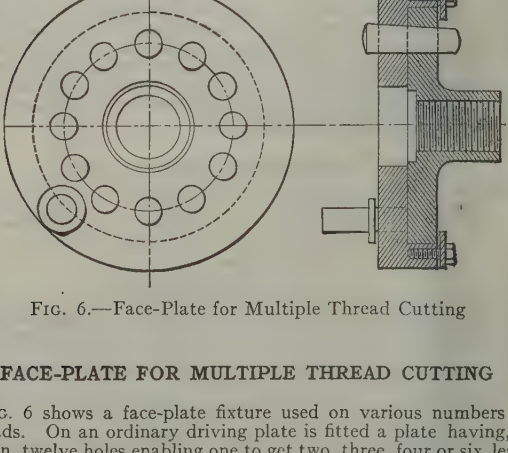


FIG. 6.—Face-Plate for Multiple Thread Cutting

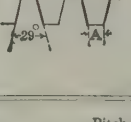
FACE-PLATE FOR MULTIPLE THREAD CUTTING

FIG. 6 shows a face-plate fixture used on various numbers of threads. On an ordinary driving plate is fitted a plate having, as shown, twelve holes enabling one to get two, three, four or six leads if required. This ring carries the driving stud, and is clamped at the back of the plate by two volts as an extra safeguard. All that is necessary in operation is to slack off the bolts, withdraw the index pin, move the plate the number of holes required, and re-tighten the bolts. It is used on different lathes, as occasion requires, by making the driving plates alike and drilling a hole for the index pin. It is found that the index pin works best when made taper, and a light tap is sufficient to loosen or fix it.

CUTTING DIAMETRAL PITCH WORMS IN THE LATHE

THE accompanying table is to be used in cases where fractional worm-thread cutting is necessary for diametrical pitch worm threads to mesh into diametral-pitch worm gears.

TABLE OF CHANGE GEARS FOR DIAMETRAL PITCH WORMS



Diametral Pitch	Single Depth	Width of Tool Point A	Width of Top of Thread B	Pitch of Lead Screw							
				2	3	4	5	6	7	8	10
2	1.078″	.487″	.526″	1/2	2/3	4/4	5/5	8/8	7/7	8/8	10/10
2½	.862″	.390″	.421″	88/56	132/56	176/56	44/28	264/56	44/28	352/56	440/56
3	.719″	.325″	.350″	44/21	32/21	88/21	110/21	44/21	22/21	176/21	220/21
3½	.616″	.278″	.300″	88/49	132/49	176/49	220/49	264/49	44/49	352/49	440/49
4	.540″	.243″	.263″	1/4	3/4	2/4	5/4	2/4	1/4	4/4	5/4
5	.431″	.195″	.210″	44/36	88/36	88/36	22/36	132/36	22/36	176/36	44/36
6	.360″	.162″	.175″	22/24	1/4	44/24	55/24	22/24	1/4	88/24	110/24
7	.308″	.139″	.150″	44/28	88/28	88/28	110/28	132/28	22/28	176/28	220/28
8	.270″	.122″	.131″	11/8	3/8	1/8	5/8	3/8	1/8	2/8	5/8
9	.240″	.108″	.117″	44/36	88/36	88/36	110/36	44/36	22/36	176/36	220/36
10	.216″	.097″	.105″	22/20	33/20	44/20	1/4	66/20	11/20	88/20	22/20
11	.196″	.088″	.096″	4/4	6/4	4/4	10/4	12/4	14/4	16/4	20/4
12	.180″	.081″	.088″	11/12	11/12	22/12	55/12	11/12	11/12	44/12	55/12
14	.154″	.069″	.075″	22/28	33/28	44/28	55/28	66/28	11/28	88/28	110/28
16	.135″	.061″	.066″	11/16	33/32	22/16	55/32	33/16	77/32	11/16	55/32
18	.120″	.054″	.058″	22/63	11/21	44/63	55/63	33/21	11/21	88/63	110/63
20	.108″	.048″	.053″	11/10	33/20	22/10	11/4	33/20	77/40	22/10	11/4
24	.090″	.040″	.044″	11/12	11/12	11/12	55/48	33/24	77/48	22/12	55/48
28	.077″	.034″	.038″	11/14	33/28	22/28	55/56	33/28	11/14	44/28	55/56
32	.067″	.030″	.033″	11/16	33/32	11/16	55/64	33/32	11/16	11/16	55/64
40	.054″	.024″	.026″	11/20	33/40	11/20	11/8	33/40	11/20	33/40	11/8
48	.045″	.020″	.022″	11/24	11/24	11/24	55/96	11/24	11/24	11/24	11/24

Formula: $\left.\begin{matrix}22 \times \text{Lead screw} \\ 7 \times \text{Diametral pitch}\end{matrix}\right\} =$ Ratio of wheels.

The ratio 355:113 is more accurate than 22:7 but requires odd gears; a 71-tooth gear and a 5:1 compound gives 355.

In the first column is found the diametral pitch to be cut. In the second column is found the corresponding single depth of the worm thread. Under the third column is found the width of the tool at the point, the tool being the regular 29-degree included angle. In the fourth column is found the width at the top of the worm thread.

The next heading in the chart is "Pitch of lead screw," and here are found different pitches of lead screws 2 to 10.

Example: Suppose it is desired to cut a worm thread of 4 diametral pitch on a single-geared lathe having a 6-pitch lead screw. Opposite 4 in the first column find the single depth of worm thread, or 0.540 inch; and continuing in the same direction from left to right, under the next column find the width of the worm-thread tool at the point or end, which is 0.243 inch, and so on to the next column, where is found the width of the worm thread at the top, which is 0.263 inch. Say there is a 6-pitch lead screw on the lathe. Then follow right on in the same direction to the column headed 6, which shows the gear ratio to be $\frac{3}{7}\frac{3}{2}$. Of course, there is no 7 gear on the lathe, so simply bring the fraction $\frac{3}{7}\frac{3}{2}$ to higher denominations, say $\frac{3}{7}\frac{3}{2} \times \frac{3}{3} = \frac{9}{2}\frac{9}{1}$: that is, put the 99 gear on the spindle or stud, and the 21 gear on the screw. Then use a gear of any convenient size to act as an intermediate gear, and thus connect the gear on the spindle with the gear on the screw. Taking the fraction $\frac{3}{7}\frac{3}{2}$ and multiplying the numerator and denominator by 4 would give $\frac{1}{2}\frac{3}{8}\frac{2}{}$ as the two gears to be used. It will be seen that this last fraction simply changes the number of teeth in the gears, but does not change the value of the fraction; thus there is the same ratio of gears.

Take another case: Suppose it is desired to cut a 20-diametral pitch worm thread in a lathe having a 4-pitch lead screw. What would be the necessary gears to cut the desired thread? Next to 20 in the first column is found the single depth of the worm thread, which is 0.018 inch. Read from left to right as in the first case, and 0.048 inch is found as the width of the tool at the point. In the next column is found the width at the top of the worm thread, which in this case is 0.053 inch. Under column 4, and opposite 20, are found the gears necessary for cutting a 20-diametral pitch worm thread in a lathe with a 4-pitch lead screw. The gears thus found, namely, $\frac{22\text{ stud}}{35\text{ screw}}$ may not be in the regular set of gears furnished with the lathe. In that case double up on both and make it $\frac{44\text{ stud}}{70\text{ screw}}$, which is the same in value. The two examples thus worked out could have been cut on lathes with lead screws having any number of threads per inch, with the same result. One point in cutting these threads is that the tool must be of exact dimensions all over, for if it is not exactly 29 degrees included angle, or the point is not as it should be for width, then there will be an error in the worm thread all around.

THE BROWN & SHARPE 29-DEGREE WORM THREAD AND THE ACME 29-DEGREE STANDARD SCREW THREAD

THERE seems to be some confusion among mechanics regarding the 29-degree Acme standard screw thread and the Brown & Sharpe 29-degree worm thread.

The sketches, Figs. 7 and 8, show plainly the difference between threads of the same pitch in the two systems. The sectional

views are of threads of one-inch linear pitch drawn to scale to the proportions given by the thread formulas in connection with the complete tables of the two systems of threads as given on pages following. The clearance for bottom of thread is the same, 0.010 inch, for all pitches. See pages 15 and 16 for correct dimensions.

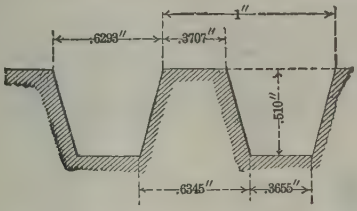


FIG. 7. — Acme 29-Degree Screw Thread

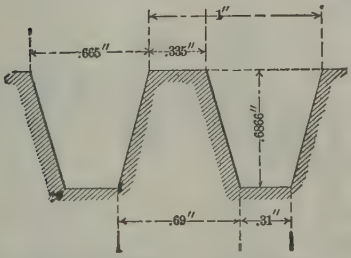


FIG. 8.—Brown & Sharpe 29-Degree Worm Thread

The worm thread is based on the linear pitch of the worm and proportions figured same as rack tooth with varying clearances in bottom. B. & S. 29-degree screw thread has a uniform clearance of 0.005 inch for all pitches. Do not confuse the two threads.

MEASUREMENT OF THREAD TOOLS

THE table of angle measurements that follows should prove of convenience to all who make tools for cutting angles or make the gages for these tools.

The principle here adopted is that, on account of the difficulty and in some cases the impossibility of measuring the tool at its point, the measurement is taken on the angle of the tool at a given distance from the point. In this case the true measurement will be less than the actual measurement by an amount equal to twice the tangent of half of the angle, multiplied by the distance of the line of measurement from the point.

For making the measurement the Brown & Sharpe gear-tooth caliper may be used. Fig 9. shows this tool in position for measuring. The depth vernier A is set to a given depth h, and the measurement is taken by means of the vernier B. The width of the tool point x is equal to the measurement on the line $a\,b$ less $2h\left(tan.\frac{C}{2}\right)$

To use the table, h is always taken to be $\frac{1}{16}$ inch, which is found to be a convenient depth for most work. If a greater depth is required, all that is necessary is to multiply the figures given by the ratio of the required depth to $\frac{1}{16}$ inch. For instance, if the depth is required to be $\frac{1}{8}$ inch, the figures given are multiplied by 2. In the great majority of cases, $\frac{1}{16}$ will be found a suitable value for h

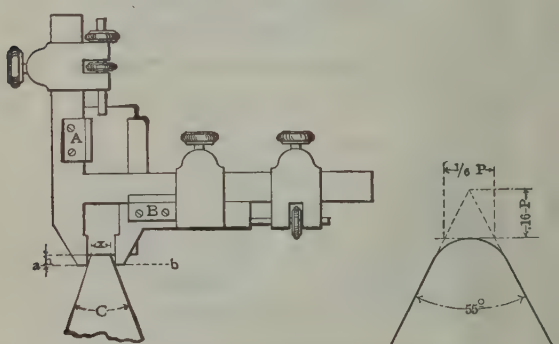


FIG. 9.—Measuring Thread Tools

when to find the width of the point x it is merely necessary to deduct the value of $\frac{tan.\frac{C}{2}}{8}$ for the angle required, which can be obtained at a glance from the table.

In the case of the American or United States standard thread, the point of the tool should be one-eighth of the pitch of the screw, while in the Whitworth standard, as shown, the point of the tool would be one-sixth of the pitch if it were not rounded. By using these figures in combination with the table, it can be determined when sufficient has been ground from the point of the tool.

The table is called "Table for Angle Measurements," because if a sharp angle, that is, one without the point ground away, is measured as above, this measurement, by reference to the table, will give the angle direct.

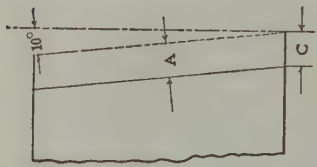
TABLE FOR THREAD TOOL ANGLE MEASUREMENTS

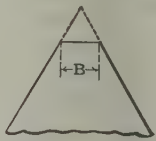
Degrees	$\frac{\tan \frac{C}{2}}{8}$	Degrees	$\frac{\tan \frac{C}{2}}{8}$	Degrees	$\frac{\tan \frac{C}{2}}{8}$
1	0.0011	31	0.0346	61	0.0736
2	0.0022	32	0.0358	62	0.0751
3	0.0033	33	0.0370	63	0.0766
4	0.0044	34	0.0382	64	0.0781
5	0.0055	35	0.0394	65	0.0796
6	0.0066	36	0.0406	66	0.0811
7	0.0077	37	0.0418	67	0.0827
8	0.0088	38	0.0430	68	0.0843
9	0.0099	39	0.0442	69	0.0859
10	0.0110	40	0.0454	70	0.0875
11	0.0121	41	0.0466	71	0.0891
12	0.0132	42	0.0489	72	0.0908
13	0.0143	43	0.0492	73	0.0925
14	0.0154	44	0.0505	74	0.0942
15	0.0165	45	0.0518	75	0.0959
16	0.0176	46	0.0531	76	0.0976
17	0.0187	47	0.0544	77	0.0994
18	0.0198	48	0.0557	78	0.1012
19	0.0209	49	0.0570	79	0.1030
20	0.0220	50	0.0583	80	0.1048
21	0.0231	51	0.0596	81	0.1067
22	0.0242	52	0.0609	82	0.1086
23	0.0253	53	0.0623	83	0.1105
24	0.0264	54	0.0637	84	0.1125
25	0.0275	55	0.0651	85	0.1145
26	0.0286	56	0.0665	86	0.1165
27	0.0298	57	0.0679	87	0.1186
28	0.0310	58	0.0693	88	0.1207
29	0.0322	59	0.0707	89	0.1228
30	0.0334	60	0.0721	90	0.1250

GRINDING THE FLAT ON THREAD TOOLS

To facilitate grinding the correct width of flat for the single-point inserted tool to cut American standard form of threads, the table on page 14 shows flats for commonly used threads. The distance from the point of the tool to the back is first measured with the micrometer, then the point of the tool may be ground off until the micrometer measurement from the back is equal to the whole depth minus dimension A, when we may be sure, without undertaking the difficult job of measuring it directly, that the flat B has the proper width. The dimensions A and B for pitches from 1 to 64 threads per inch are included in the table.

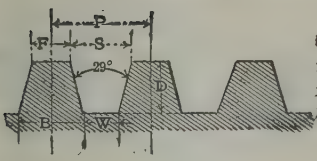
Table for Grinding Flat End of Tool for American Form of Thread





Threads per Inch	Pitch	A	B	C	Double Depth	Depth
1	1.000	.1064	.125	.1082	1.299	.6495
2	.5000	.0532	.0625	.0541	.6495	.3247
3	.3333	.0355	.0416	.0360	.433	.2165
4	.2500	.0266	.0312	.0270	.3247	.1623
5	.2000	.0213	.0250	.0216	.2598	.1299
6	.1666	.0177	.0208	.0180	.2165	.1082
7	.1428	.0152	.0178	.0154	.1855	.0927
8	.1250	.0133	.0156	.0135	.1623	.0812
9	.1111	.0118	.0138	.0120	.1443	.0721
10	.1000	.0106	.0125	.0108	.1299	.0649
11	.0909	.00963	.0113	.0098	.1180	.0592
12	.0833	.00886	.0104	.0090	.1082	.0541
13	.0769	.00818	.0096	.0083	.0999	.0499
14	.0714	.00758	.0089	.0077	.0920	.0460
15	.0666	.00707	.0083	.0071	.0866	.0433
16	.0625	.00673	.0079	.0068	.0812	.0406
17	.0588	.00620	.0073	.0063	.0764	.0382
18	.0555	.00588	.0069	.0059	.0721	.0360
19	.0526	.00554	.0065	.0056	.0683	.0341
20	.0500	.00530	.0062	.0054	.0649	.0324
21	.0476	.00503	.0059	.0051	.0618	.0309
22	.0454	.0048	.0056	.0049	.0590	.0295
23	.0431	.00451	.0053	.0046	.0564	.0282
24	.0416	.00433	.0052	.0045	.0541	.0270
25	.0400	.00426	.0050	.0043	.0519	.0259
26	.0384	.00409	.0048	.0041	.0491	.0245
27	.0370	.00393	.0046	.0040	.0481	.0240
28	.0357	.00375	.0044	.0038	.0463	.0231
29	.0344	.00366	.0043	.0037	.0447	.0223
30	.0333	.00354	.0041	.0036	.0433	.0216
31	.0322	.00341	.0040	.0035	.0419	.0209
32	.0312	.00332	.0039	.0034	.0405	.0202

ACME 29° SCREW THREADS



The Acme standard thread is an adaptation of the most commonly used style of Worm Thread and is intended to take the place of the square thread.

It is a little shallower than the worm thread, but the same depth as the square thread and much stronger than the latter.

The various parts of the Acme standard thread are obtained as follows:

Width of Point of Tool for Screw Thread =

$$\frac{.3707}{\text{No. of Threads per inch}} - .0052.$$

Width of Screw or Nut Thread $= \dfrac{.3707}{\text{No. of Threads per inch}}$.

Diameter of Screw at Root =

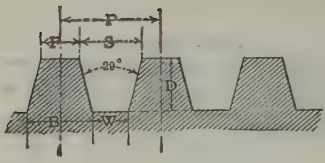
$$\text{Diameter of Screw} - \left(\frac{1}{\text{No. of Threads per inch}} + .020\right).$$

Depth of Thread $= \dfrac{1}{2 \times \text{No. of Threads per inch}} + .010.$

TABLE OF ACME 29° SCREW THREAD PARTS

N	P	D	F	W	S	B
Number of Threads per Inch	Pitch of Single Thread	Depth of Thread	Width of Top of Thread	Width of Space at Bottom of Thread	Width of Space at Top of Thread	Thickness at Root of Thread
1	1.0	.5100	.3707	.3655	.6293	.6345
1½	.750	.3850	.2780	.2728	.4720	.4772
2	.500	.2600	.1853	.1801	.3147	.3199
3	.3333	.1767	.1235	.1183	.2098	.2150
4	.250	.1350	.0927	.0875	.1573	.1625
5	.200	.1100	.0741	.0689	.1259	.1311
6	.1666	.0933	.0618	.0566	.1049	.1101
7	.1428	.0814	.0529	.0478	.0899	.0951
8	.125	.0725	.0463	.0411	.0787	.0839
9	.1111	.0655	.0413	.0361	.0699	.0751
10	.10	.0600	.0371	.0319	.0629	.0681

ACME 29° TAP THREADS



N = No. of Threads per Inch

$P = \frac{1}{N}$ = Linear Pitch

D = .5 P + .02

F = .3707 P − .0052

W = .3707 P − .0052

S = .6293 P + .0052

B = .6293 P + .0052

THE Acme standard tap-thread is cut with the same width of tool as the screw-thread and the diameter at the root is the same for tap and screw. Clearance at bottom of thread between screw and nut is obtained by boring the nut blank .020 oversize.

The outside diameter of the tap is made .020 larger than the screw to give clearance between top of screw-thread and bottom of nut.

Width of Point of Tool for Tap-Thread =

$$\frac{.3707}{\text{No. of Threads per Inch}} - .0052.$$

$$\text{Width of Thread} = \frac{.3707}{\text{No. of Threads per Inch}} - .0052$$

$$\text{Diameter of Tap} = \text{Diameter of Screw} + .020.$$

Diameter of Tap at Root =

$$\text{Diameter of Tap} - \left(\frac{1}{\text{No. of Threads per Inch}} + .040.\right)$$

$$\text{Depth of Thread} = \frac{1}{2 \times \text{No. of Threads per Inch}} + .020.$$

TABLE OF ACME STANDARD 29° TAP-THREAD PARTS

N	P	D	F	W	S	B
Number of Threads per Inch	Pitch of Single Thread	Depth of Thread	Width of Top of Thread	Width of Space at Bottom of Thread	Width of Space at Top of Thread	Thickness at Root of Thread
1	1.0	.5200	.3655	.3655	.6345	.6345
1½	.750	.3950	.2728	.2728	.4772	.4772
2	.500	.2700	.1801	.1801	.3199	.3199
3	.3333	.1867	.1183	.1183	.2150	.2150
4	.250	.1450	.0875	.0875	.1625	.1625
5	.200	.1200	.0689	.0689	.1311	.1311
6	.1666	.1033	.0566	.0566	.1101	.1101
7	.1428	.0914	.0478	.0478	.0951	.0951
8	.125	.0825	.0411	.0411	.0839	.0839
9	.1111	.0755	.0361	.0361	.0751	.0751
10	.10	.0700	.0319	.0319	.0681	.0681

SCREW-THREAD MEASUREMENTS

Screw threads are no longer measured by their outside diameter, but by the pitch diameter, using either micrometers with special points that bear only on the thread angle, wires laid in the threads and measured across the outside, or optical methods that compare a magnified image of the thread with a standard pattern. The first two methods are more common than the latter, although the optical method is being more widely used.

SCREW-THREAD MICROMETER CALIPER

The thread micrometer is fitted with pointed spindle and "V" anvil, as in Fig. 10, to measure the actual thread on the cut surface. Enough of the point is removed and the bottom of the "V" is carried low enough so that the anvil and spindle clear the top and bottom of the thread and rest directly on the sides of the thread. As it measures one-half of the depth of the thread from the top, on each side, the diameter of the thread, as indicated by the caliper, is the pitch diameter, or the full size of the piece less the depth of one thread.

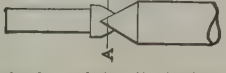


Fig. 10.—Spindle and Anvil of Thread Micrometer

This depth may be found as follows:

Depth of V threads = 0.866 ÷ number of threads to 1 inch

Depth of American threads = 0.6495 ÷ number of threads to 1 inch

Depth of Whitworth threads = 0.64 ÷ number of threads to 1 inch

As the U. S. thread is flatted one-eighth of its own depth on top, it follows that the pitch diameter of the thread is increased one-eighth on each side, equaling one-fourth of the whole depth and, instead of the constant 0.866, we use the constant 0.6495, which is three-fourths of 0.866.

When the point and anvil are in contact the 0 represents a line drawn through the plane AB, Fig. 10, and if the caliper is opened, say to 0.500, it represents the distance of the two planes 0.500 inch apart. The pitch diameters of standard threads are given on pages 47 and 55. See pages 31 and 32.

MEASURING ACME 29-DEGREE THREADS

The diameter of a wire which will be flush with tops of thread on tap when laid in the Acme thread groove, Fig. 11, will be found as follows:

Rad. of wire section = side opp. = side adj. $\times$ tan. $37^\circ 45' =$

$$\frac{p \times .6293 + .0052}{2} \times .77428.$$

Diam. of wire = $(p \times .6293 + .0052)$ .77428.

Wires of the diameter given in the table come flush with the tops of tap threads and project .010 above the top of screw threads.

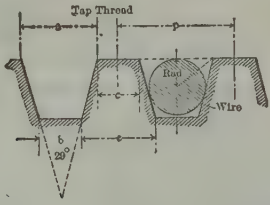


FIG. 11.—Measuring Acme Threads

TABLE OF WIRE SIZES FOR MEASURING ACME STANDARD 29° SCREW AND TAP THREADS

Threads per Inch	Pitch	Diam. of Wire
1	1.	0.4913
1½	.750	0.3694
1⅔	.6666	0.3288
1¾	.5774	0.2824
2	.500	0.2476
2½	.400	0.1989
3	.3333	0.1664
4	.250	0.1258
5	.200	0.1014
6	.1666	0.0852
7	.1428	0.0736
8	.125	0.0649
9	.1111	0.0581
10	.100	0.0527

MEASURING BROWN & SHARPE 29-DEGREE WORM THREADS

THE diameter of wire for Brown & Sharpe worm thread, Fig. 12, for each pitch, that will rest in the thread groove on the thread angle and be flush with the tops of the finished threads, is found as follows;

Rad. of wire section (see table) = side opp. = side adj. × tan. 37° 45′ $= \frac{0.665\ P}{2} \times 0.77428 = 0.257447\ P$ and diam. of wire = $0.5149\ P$.

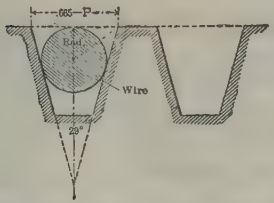
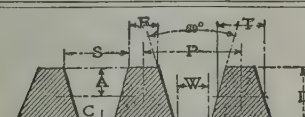


FIG. 12.—Measuring Brown & Sharpe Worm Threads

TABLE OF WIRE SIZES FOR MEASURING B. & S. 29° WORM THREADS

Threads per Inch	Pitch	Diam. of Wire
$\frac{1}{2}$	2.	1.0298
$\frac{4}{7}$	1.750	0.9010
$\frac{1}{2}$	1.500	0.7723
$\frac{4}{5}$	1.250	0.6436
1	1.0	0.5149
$1\frac{1}{2}$	.6666	0.3432
2	.5	0.2574
$2\frac{1}{2}$	.4	0.2060
3	.3333	0.1716
$3\frac{1}{2}$	.2857	0.1471
4	.250	0.1287
$4\frac{1}{2}$	.2222	0.1144
5	.2	0.1030
6	.1666	0.0858
7	.1428	0.0735
8	.125	0.0643
9	.1111	0.0572
10	.10	0.0515
12	.0833	0.0429
16	.0625	0.0322
20	.050	0.0257



N = No. of Threads per Inch.
$P = \frac{1}{N}$ = Linear Pitch
D = .6866 P
F = .335 P
W = .31 P
T = .5 P
A = .3183 P
$C = \frac{P}{10}$
S = .655 P
B = .69 P

$$\text{Pitch} = \frac{1}{\text{No. of Threads per inch}}.$$

$$\text{Depth of Thread} = \frac{.6866}{\text{No. of Threads per inch}}.$$

$$\text{Width of Top of Thread} = \frac{.335}{\text{No. of Threads per inch}}$$

$$\text{Width of Space at Bottom} = \frac{.310}{\text{No. of Threads per inch}}$$

$$\text{Clearance at Bottom of Thread} = \frac{\text{Thickness at Pitch Line}}{10}$$

$$\text{Width of Space at Top of Thread} = \frac{.665}{\text{No. of Threads per inch}}$$

$$\text{Thickness at Root of Thread} = \frac{.69}{\text{No. of Threads per inch}}$$

TABLE OF BROWN & SHARPE 29° WORM THREAD PARTS

Number of Threads Per Inch	P Pitch of Single Thread	D Depth of Thread	F Width of Top of Thread	W Width of Space at Bottom	T Thickness of Thread at Pitch Line	A Thread Above Pitch Line	C Clearance at Bottom of Thread	S Width of Space at Top	B Thickness at Root of Thread
1	1.0	.6866	.3350	.3100	.5000	.3183	.05	.665	.69
1¼	.8	.5492	.2680	.2480	.4000	.2546	.04	.532	.552
1½	.6666	.4577	.2233	.2066	.3333	.2122	.0333	.4433	.4599
2	.5	.3433	.1675	.1550	.2500	.1592	.0250	.3325	.345
2½	.4	.2746	.1340	.1240	.2000	.1273	.0200	.2660	.276
3	.3333	.2289	.1117	.1033	.1666	.1061	.0166	.2216	.2299
3½	.2857	.1962	.0957	.0886	.1429	.0909	.0143	.1901	.2011
4	.250	.1716	.0838	.0775	.1250	.0796	.0125	.1637	.1725
4½	.2222	.1526	.0744	.0689	.1111	.0707	.0111	.1478	.1533
5	.2	.1373	.0670	.0620	.1000	.0637	.0100	.1330	.138
6	.1666	.1144	.0558	.0517	.0833	.0531	.0083	.1108	.115
7	.1428	.0981	.0479	.0443	.0714	.0455	.0071	.095	.0985
8	.125	.0858	.0419	.0388	.0625	.0398	.0062	.0818	.0862
9	.1111	.0763	.0372	.0344	.0555	.0354	.0055	.0739	.0766
10	.10	.0687	.0335	.0310	.0500	.0318	.005	.0665	.069
12	.0833	.0572	.0279	.0258	.0416	.0265	.0042	.0551	.0575
16	.0625	.0429	.0209	.0194	.0312	.0199	.0031	.0409	.0431
20	.050	.0343	.0167	.0155	.0250	.0159	.0025	.0332	.0345

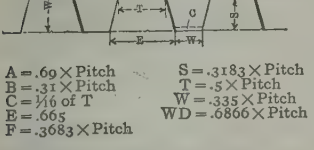
WORM WHEEL HOBS

HOBS are made larger in diameter than the worm they are used with by the amount of two clearances. The Brown & Sharpe method is to make the clearance one-tenth of the thickness of the tooth on the pitch line or .05 inch for a worm of one pitch. If the worm was 3 inches outside diameter, which would be a fair proportion for this pitch, the outside diameter of the hob would be 3 +

(2 × .05) = 3.1 inches. The thread tool would be .335 inch wide at the point and would cut .6366 + .05 = .6866 deep, leaving the top of the thread .31 inch thick and the bottom .335 inch thick.

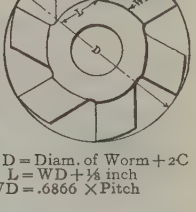
The land *L* should be made as near the proportions given as possible.

The diagram, Fig. 13, shows the shape and proportions of the thread of a worm hob, and Fig. 14 shows the proportions for the



A = .69 × Pitch
B = .31 × Pitch
C = 1/16 of T
E = .665
F = .3683 × Pitch
S = .3183 × Pitch
T = .5 × Pitch
W = .335 × Pitch
WD = .6866 × Pitch

FIG. 13.—Section of Hob Thread



D = Diam. of Worm + 2C
L = WD + 1/8 inch
WD = .6866 × Pitch

FIG. 14.—End View of Hob

depth of tooth, the lead and the outside diameter. In these diagrams:

A = Width of space at top of tooth.
B = Width of thread at top.
C = Clearance or difference between the hob and worm.
D = Diameter of hob.
E = Width of tooth at bottom.
F = Height above pitch line.
L = Width of land or tooth at bottom.
S = Depth below pitch line.
T = Width at pitch line.
W = Width of space at bottom.
WD = Whole depth of tooth.

Brown & Sharpe allow clearance at the point of the tooth only for worm wheels, but at both point and bottom when hobbing spur gears.

WATCH SCREW THREADS

WATCH screw threads are of sharp V-form and generally 45-degree angle for screws used in nickel and brass; though 60 degrees for use in steel. The Waltham Watch Company and others use the centimeter as the unit for all measurements with the exception of the pitch, which is based on the inch; the Waltham threads being 110, 120, 140, 160, 170, 180, 200, 220, 240, 254, per inch and the diameters ranging from 0.120 to 0.035 cm. See page 84.

MEASURING THREADS BY THE THREE-WIRE METHOD

The three-wire method of measuring the pitch diameter of screws is recommended by the Bureau of Standards as the best means of securing uniformity. By placing the three wires, of correct diameter, in the threads, as shown in Fig. 15, and measuring over them, the pitch diameter can be found directly by subtracting the wire constant from the measured diameter. This simplified procedure results only when the *best* wire for the pitch of the screw is used.

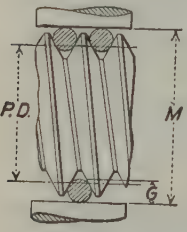


FIG. 15

The *best* wire is the size of wire which touches the thread at the middle of the sloping sides. Inasmuch as the *pitch diameter* is defined as the diameter of the screw where the land and space are equal (this occurs at the middle of the sloping sides), the *best* wire touches the thread at the pitch diameter. Also, measurements of pitch diameter with *best* wires are true measurements, although slight variations are present in the angle of thread.

The wires used should be hardened and lapped steel wires and should be *three* times as accurate as the accuracy of the measurements desired. Bureau of Standards specifications call for an accuracy of 0.00002 inch.

The general formula for computing the measured pitch diameter of a screw is:

$$E = M + \frac{\cot a}{2N} - G(1 + \operatorname{cosec} a)$$

where M = measurement over
PD = pitch diameter
E = pitch diameter.
G = diameter of best wire.
N = number of threads per inch.
a = ½ of the included angle of thread.

For a 60-degree thread, which included American coarse and National fine threads and also 60-degree metric threads, his formula reduces as follows:

$$E = M + \frac{1.73205}{2N} - G(1 + 2.00000).$$

And this reduces further to

$$E = M + \frac{0.86602}{N} - 3G.$$

Now it so happens for a 60-degree thread that the depth of a sharp V thread is $\frac{0.86602}{N}$ and that $3G$ or three times the diameter of the

best wire is just twice $\frac{0.86602}{N}$, so the formula is further simplified to:

$$E = M - \text{depth of V thread.}$$

The first column on page 24 shows the number of threads per inch, the second the diameter of the best wire G to use for the different pitches, then the wire constant or depth of a V thread H, next depth of American thead h, and the smallest and largest wires that can be used. The formula for each is given at the top of the column. A contact pressure of 2 pounds is recommended in making wire measurements.

Measuring the Thread Angle

The angle of thread can be checked by using wires of two sizes and measuring over each, then calculated by the following formula. Using the maximum wire G_1 and the minimum wire G_2 and calling the maximum measurement M_1 and the minimum measurement M_2, the formula is $\frac{M_1 - M_2}{G_1 - G_2}$. When this equals 3.0000 the angle is 60 degrees. For other angles the following results will be obtained:

The following is an example of measuring a ½-inch, 13-pitch American coarse thread:

Major diameter	0.5000 inch
Number Threads per inch	13
Best wire size	0.04441 inch
Measurement over wires	0.5169 inch
Wire constant	0.06662 inch
G_1 maximum wire size	0.06415 inch
G_2 minimum wire size	0.04124 inch
M_1 measurement over maximum wires	0.5811 inch
M_2 measurement over minimum wires	0.5122 inch

The measured pitch diameter is 0.5169 − 0.06662 = 0.45028 inch. The nominal or basic pitch diameter should be specified on the shop drawing, but if not, it is found by subtracting the depth of thread h from the major diameter. Thus the basic pitch diameter is 0.5000 − 0.04996 = 0.45004 inch. The thread measured is, therefore, 0.00024 inch oversize.

If we substitute the measurements obtained with the maximum and minimum wires in the formula for angle, the result is:

$$\frac{0.5811 - 0.5122}{0.06415 - 0.04124} = \frac{0.0689}{0.02291} = 3.0074.$$

From the table of results of angle computations it is found that 3.0101 corresponds to an angle of 59 degrees 40 minutes and the result 3.0050 to 59 degrees 50 minutes. The result obtained in the ½-inch 13-pitch example is about halfway between 3.0101 and 3.0050, and the angle of thread is therefore 59 degrees 45 minutes.

Three Wire Measurement of American Thread
(Dimensions in Inches)

No. Threads per Inch	$G = \frac{0.57735}{N}$ Diam. Best Wire	Best Wire Constant $H = \frac{0.86602}{N}$ Depth V Thread	$h = \frac{0.64951}{N}$ Depth American Thread	N = No. Threads per Inch	
				Min. Wire	Max. Wire
80	0.00722	0.01083	0.00812	0.00722	0.01155
72	0.00802	0.01203	0.00902	0.00802	0.01312
64	0.00902	0.01353	0.01014	0.00902	0.01443
56	0.01031	0.01546	0.01160	0.01031	0.01604
50	0.01155	0.01732	0.01299	0.01155	0.01804
48	0.01203	0.01804	0.01353	0.01155	0.02062
44	0.01312	0.01968	0.01476	0.01155	0.02221
40	0.01443	0.02165	0.01624	0.01312	0.02406
36	0.01604	0.02406	0.01804	0.01443	0.02624
32	0.01804	0.02706	0.02030	0.01604	0.02887
30	0.01924	0.02887	0.02161	0.01804	0.03039
28	0.02062	0.03093	0.02319	0.01924	0.03207
26	0.02221	0.03331	0.02498	0.02062	0.03608
24	0.02406	0.03608	0.02706	0.02221	0.03608
22	0.02624	0.03936	0.02952	0.02406	0.04124
20	0.02887	0.04330	0.03248	0.02624	0.04441
19	0.03039	0.04558	0.03418	0.02887	0.04811
18	0.03207	0.04811	0.03608	0.02887	0.05020
16	0.03608	0.05413	0.04060	0.03207	0.05774
14	0.04124	0.06186	0.04640	0.04124	0.06415
13	0.04441	0.06662	0.04996	0.04124	0.06415
12	0.04811	0.07217	0.05413	0.04441	0.07217
11½	0.05020	0.07531	0.05648	0.04811	0.07217
11	0.05249	0.07873	0.05904	0.05020	0.08248
10	0.05774	0.08660	0.06495	0.05249	0.09622
9	0.06415	0.09622	0.07218	0.05774	0.09622
8	0.07217	0.10825	0.08119	0.06415	0.10497
7	0.08248	0.12372	0.09279	0.07217	0.12830
6	0.09622	0.14434	0.10825	0.09622	0.14434
5½	0.10497	0.15746	0.11805	0.09622	0.14434
5	0.11547	0.17320	0.12990	0.10497	0.14434
4½	0.12830	0.19245	0.14434	0.11547	0.14434
4	0.14434	0.21651	0.16238	0.12830	

Note.—Sometimes taps have an outside diameter over basic, and the minimum wires given may not project above the tops of the thread.

With 60-degree threads H = both the depth of a V thread and also the best wire constant.

Formula for American 60-degree Threads

Basic pitch diam. = Basic outside diam. − Depth American threads.
Measured pitch diam. = M + Depth V. Threads − $3G$.
If best wire is used,

Measured pitch diam. = M − best wire constant.

Checking Angle of Thread

Using two sizes of wires, G_1 (large) and G_2 (small).
If angle is 60 degrees then

$$\frac{M_1 - M_2}{G_1 - G_2} = 3.0000.$$

For other angles the following results will be obtained:

Result	Angle	
	Degrees	Minutes
3.0152	59	30
3.0101	59	40
3.0050	59	50
3.0000	60	
2.9950	60	10
2.9900	60	20
2.9850	60	30

Wire Sizes and Constants for 55-Degree Threads

This includes British Standard Whitworth and British Standard Fine Threads

No. Threads per Inch	Diam. Best Wire $= G = \frac{0.563602}{N}$	Depth of V Thread 55 Degrees $= H = \frac{0.96049}{N}$	$h = 0.6403 \frac{1}{N} =$ Depth of Whitworth Thread	Diam. Min. Wire	Diam. Max. Wire	Best Wire Constant $= \frac{0.82398}{N}$
40	0.01409	0.02401	0.01601	0.01409	0.02013	0.02060
36	0.01566	0.02668	0.01779	0.01409	0.02168	0.02289
32	0.01762	0.03002	0.02001	0.01762	0.02563	0.02577
28	0.02013	0.03430	0.02287	0.02013	0.02818	0.02943
26	0.02168	0.03694	0.02463	0.02013	0.03132	0.03169
24	0.02349	0.04002	0.02668	0.02349	0.03525	0.03433
22	0.02563	0.04366	0.02911	0.02349	0.03525	0.03745
20	0.02818	0.04802	0.03202	0.02563	0.04026	0.04120
18	0.03132	0.05336	0.03557	0.02818	0.04697	0.04577
16	0.03525	0.06003	0.04002	0.03525	0.05124	0.05155
14	0.04026	0.06861	0.04574	0.04026	0.05637	0.05886
12	0.04697	0.08004	0.05336	0.04697	0.07046	0.06866
11	0.05124	0.08732	0.05821	0.04697	0.07046	0.07491
10	0.05637	0.09605	0.06403	0.05124	0.08053	0.08240
9	0.06263	0.10672	0.07115	0.05637	0.09396	0.09155
8	0.07046	0.12006	0.08004	0.07046	0.09396	0.10300
7	0.08053	0.13721	0.09148	0.08053	0.11274	0.11771
6	0.09396	0.16008	0.10672	0.09396	0.14092	0.13733
5	0.11274	0.19210	0.12807	0.09396	0.14092	0.16480
4½	0.12526	0.21344	0.14230	0.11274	0.16105	0.18311
4	0.14092	0.24012	0.16008	0.14092	0.16105	0.20600
3½	0.16105	0.27443	0.18295	0.16105		0.23542

Formula for 55-degree Threads

Basic pitch diam. = Basic outside diam. − Depth of thread.

$$\text{Measured pitch diam} = M + \frac{0.09049}{N} - 3.16568\,G.$$

If best size wire is used, then the

Measured pitch diam. = M − best wire constant.

Checking Angle of Thread

Using two sizes of wires, G_1 (large) and G_2 (small). If the angle is 55 degrees then

$$\frac{M_1 - M_2}{G_1 - G_2} = 3.1657.$$

For other angles the results shown below will be obtained:

Result	Angle	
	Degrees	Minutes
3.1840	54	30
3.1778	54	40
3.1717	54	50
3.1657	55	
3.1596	55	10
3.1536	55	20
3.1477	55	30

Wire Sizes and Constants for 60-degree Metric Threads

Pitch in Millimeters	Approx. Threads per Inch	$G = \frac{0.57735}{N}$ Diam. Best Wire	$H = \frac{0.86602}{N}$ Depth of Sharp V Thread also Best Wire Constant	$h = \frac{0.64951}{N}$ Depth of 60-degree Metric Thread in Inches	For Min. Wire Use Best Wire of Pitch Given Below	For Max. Wire Use Best Wire of Pitch Given Below
0.24	105.8	0.00546	0.00818	0.00614	0.24	0.42
0.27	94.1	0.00614	0.00921	0.00690	0.24	0.45
0.30	84.7	0.00682	0.01023	0.00767	0.27	0.45
0.33	77.0	0.00750	0.01125	0.00831	0.30	0.45
0.36	70.6	0.00818	0.01227	0.00920	0.33	0.60
0.39	65.2	0.00886	0.01330	0.00981	0.33	0.60
0.42	60.5	0.00955	0.01432	0.01073	0.36	0.60
0.45	56.4	0.01023	0.01534	0.01150	0.42	0.75
0.60	42.3	0.01364	0.02046	0.01534	0.60	1.00
0.75	33.9	0.01705	0.02557	0.01918	0.75	1.25
0.90	28.2	0.02046	0.03069	0.02302	0.90	1.50
1.00	25.4	0.02273	0.03410	0.02556	1.00	1.75
1.25	20.3	0.02841	0.04262	0.03196	1.25	2.00
1.50	16.9	0.03410	0.05114	0.03836	1.50	2.50
1.75	14.5	0.03978	0.05967	0.04475	1.75	3.00
2.00	12.7	0.04546	0.06819	0.05112	1.75	3.50
2.50	10.2	0.05683	0.08524	0.06393	2.50	4.00
3.00	8.5	0.06819	0.10229	0.07672	3.00	5.00
3.50	7.3	0.07956	0.11933	0.08950	3.50	5.50
4.00	6.4	0.09092	0.13638	0.10221	3.50	7.00
4.50	5.6	0.10229	0.15343	0.11507	4.50	7.50
5.00	5.1	0.11365	0.17048	0.12786	4.50	7.50
5.50	4.6	0.12502	0.18752	0.14064	5.00	8.00
6.00	4.2	0.13638	0.20457	0.15343	5.50	8.00
6.50	3.9	0.14775	0.22162	0.16621	6.00	8.00
7.00	3.6	0.15911	0.23867	0.17900	6.50	8.00
7.50	3.4	0.17048	0.25572	0.19179	7.00	8.00
8.00	3.2	0.18184	0.27276	0.20457	7.00	

Note.—The thread depth given above corresponds to a $\frac{1}{8}$ flat both at the top and bottom of the thread. Usually the flat at the bottom is made $\frac{1}{16}$ of the pitch to provide a greater clearance.

Formula same as American thread, including angle measurement.

Basic pitch diam. = Basic outside diam. − Depth of thread.

Measured pitch diam. = M + Depth V. Threads − $3G$.

If best wire is used, then the

Measured pitch diam. = M − best wire constant.

Wire Sizes and Constants for British Association Screw Threads

Angle of thread $47\frac{1}{2}$ degrees

Size	Pitch, Millimeters	Approx. No. Threads per Inch	Approx. Major Diam., Inches	Pitch Diam., Inches	Diam. Best Wire, Inches	Depth of V Thread $47\frac{1}{2}$ Degrees $= \frac{1.13634}{N}$, Inches	Depth of Thread in Millimeters	Diam. Min. Wire, Inches	Diam. Max. Wire, Inches	$\left(\frac{1.13634}{N} - 3.4829G\right)$ Best Wire Constant Inches
0	1.00	25.4	0.236	0.21260	0.02151	0.04474	0.6	0.02151	0.02870	0.03016
1	0.90	28.2	0.209	0.18740	0.01936	0.04026	0.54	0.01936	0.02585	0.02717
2	0.81	31.3	0.185	0.16594	0.01742	0.03624	0.485	0.01742	0.02151	0.02447
3	0.73	34.8	0.161	0.14409	0.01510	0.03266	0.44	0.01510	0.01936	0.02202
4	0.66	38.5	0.142	0.12618	0.01419	0.02953	0.395	0.01419	0.01742	0.01990
5	0.59	43.1	0.126	0.11201	0.01269	0.02640	0.355	0.01269	0.01510	0.01801
6	0.53	47.9	0.110	0.09764	0.01140	0.02371	0.32	0.01140	0.01510	0.01599
7	0.48	52.9	0.098	0.08701	0.01032	0.02147	0.29	0.01032	0.01269	0.01448
8	0.43	59.1	0.087	0.07638	0.00925	0.01924	0.26	0.00925	0.01140	0.01296
9	0.39	65.1	0.075	0.06555	0.00839	0.01745	0.235	0.00839	0.01032	0.01177
10	0.35	72.6	0.067	0.05866	0.00753	0.01566	0.21	0.00753	0.00925	0.01055
11	0.31	81.9	0.059	0.05177	0.00667	0.01387	0.185	0.00667	0.00839	0.00936
12	0.28	90.7	0.051	0.04449	0.00602	0.01253	0.17	0.00602	0.00753	0.00845
13	0.25	102.0	0.047	0.04134	0.00538	0.01118	0.15	0.00495	0.00667	0.00751
14	0.23	110.0	0.039	0.03386	0.00495	0.01029	0.14	0.00452	0.00602	0.00697
15	0.21	121.0	0.035	0.03051	0.00452	0.00939	0.125	0.00452	0.00602	0.00633

Formula for $47\frac{1}{2}$ Degree Threads—Measured pitch diam. $= M + \frac{1.13634}{N} - 3.4829G$

If the best size wire is used, which is within 0.00001 inch of the diameter given in the above table, the following formula may be used. If the wire used differs from the best wire size as given in the table, a new constant for that wire may be figured and substituted for the best-wire constant. In any case the best wire should be within 0.0005 inch of the size specified:

Measured pitch diam. $= M -$ best wire constant.

Checking Angle of Thread

Using two sizes of wires G_1 (large) and G_2 (small), then if the angle is $47\frac{1}{2}$ degrees

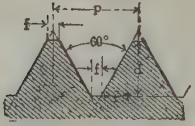
$$\frac{M_1 - M_2}{G_1 - G_2} = 3.4829.$$

For other angles the following results will be obtained:

Result	Angle	
	Degrees	Minutes
3.5078	47	
3.4995	47	10
3.4912	47	20
3.4829	47	30
3.4748	47	40
3.4666	47	50
3.4586	48	

Wire measurement tables by H. L. Van Keuren.

Dimensions of Metric Threads



Formula { p = Pitch; d = Depth = p x .6495; f = Flat = p/8 }

Diameter of Screw mm.	Pitch mm.	Diameter at Root of Thread mm.	Width of Flat mm.
3	0.5	2.35	.06
4	0.75	3.03	.09
5	0.75	4.03	.09
6	1.0	4.70	.13
7	1.0	5.70	.13
8	1.0	6.70	.13
8	1.25	6.38	.16
9	1.0	7.70	.13
9	1.25	7.38	.16
10	1.5	8.05	.19
11	1.5	9.05	.19
12	1.5	10.05	.19
12	1.75	9.73	.22
14	2.0	11.40	.25
16	2.0	13.40	.25
18	2.5	14.75	.31
20	2.5	16.75	.31
22	2.5	18.75	.31
22	3.0	18.10	.38
24	3.0	20.10	.38
26	3.0	22.10	.38
27	3.0	23.10	.38
28	3.0	24.10	.38
30	3.5	25.45	.44
32	3.5	27.45	.44
33	3.5	28.45	.44
34	3.5	29.45	.44
36	4.0	30.80	.5
38	4.0	32.80	.5
39	4.0	33.80	.5
40	4.0	34.80	.5
42	4.5	36.15	.56
44	4.5	38.15	.56
45	4.5	39.15	.56
46	4.5	40.15	.56
48	5.0	41.51	.63
50	5.0	43.51	.63
52	5.0	45.51	.63
56	5.5	48.86	.69
60	5.5	52.86	.69
64	6.0	56.21	.75
68	6.0	60.21	.75
72	6.5	63.56	.81
76	6.5	67.56	.81
80	7.0	70.91	.88

Converting American Pitch Diameters into Micrometer Reading by Three-wire Thread Measurement

Formula: $3G - (P \times 0.866025)$ = amount to add to pitch diameter. See page 33

Threads per Inch

Wire Sizes	3	3¼	3½	4	4½	5	5½	6	7	8
.1924498	*.288674	.310880	.329917							
.1776462		*.266469	.285506	.316432						
.1649572			*.247435	.278365	.302421					
.1443387				*.216509	.240566	.259811				
.1282998					*.192449	.211694	.227440			
.1154700						*.173205	.188951	.202073		
.1049727							*.157459	.170581	.191200	
.0962250								*.144338	.164957	.180421
.0824786									*.123718	.139182
.0641500										
.0721687										*.108253

Wire Sizes	9	10	11	11½	12	13	14	16	18
.0824786	.151210								
.0721687	.120281	.129903							
.0641500	*.096225	.105847	.113720						
.0577350		*.086602	.094475	.097898					
.0524863			*.078729	.082152	.085290				
.0502043				*.075306	.078444	.083995			
.0481125					*.072169	.077720	.082479		
.0444115						*.066617	.071376	.079108	
.0412303							*.061859	.069591	.075605
.0360841								*.054125	.060140
.0320741									*.048110

* Shows "Best Size" or Wire Touching on P. D.

Greenfield Tap & Die Corp.

Converting American Pitch Diameters into Micrometer Reading by Three-wire Thread Measurement

Formula: $3G - (P \times 0.866025)$ = amount to add to pitch diameter. See page 33

Threads per Inch

Wire Sizes	19	20	22	24	26	27	28	30	32	34
.0360841	.062672									
.0320741	.050642	.052921								
.0303865	*.045579	.047858	.051795							
.0288675		*.043301	.047238	.050518						
.0262431			*.039365	.042645	.045421					
.0240553				*.036082	.038857	.040092				
.0222054					*.033308	.034541	.035687			
.0213833						*.032075	.033220	.035282		
.0206194							*.030929	.032091	.034795	
.0192448								*.028867	.030671	.032263
.0180421									*.027063	.028655
.0169804										*.025470

Wire Sizes	36	40	44	48	50	56	64	72	80
.0180421	.030070								
.0169804	.026885	.029290							
.0160370	*.024055	.026460	.028428						
.0144337		*.021650	.023619	.025259					
.0131214			*.019682	.021322	.022043				
.0120279				*.018041	.018763	.020619			
.0115470					*.017320	.019176	.021109		
.0103097						*.015464	.017397	.018901	
.0090210							*.013531	.015035	.016237
.0080184								*.012027	.013229
.0072168									*.010825

* Shows "Best Size" or Wire Touching on P. D.

ROLLED THREADS

The rolled-thread process dates back more than 50 years and was first patented in England. It was first used on comparatively rough work such as track bolts, but has come to be used on such fine work as the sizing of taps and screws for micrometers.

The thread is forced up into the dies so that the finished screw is larger than the original wire by about the depth of one thread. In this way the size of the wire to use for any screw may be found by subtracting the depth of one thread from the outside diameter of the screw. Exact allowance depends on material being rolled and other conditions.

The dies are usually flat plates of steel, having grooves of the same pitch and shape as the thread to be rolled. The dies can be easily laid out as follows:

Draw a horizontal line equal in length to the circumference of the *wire* or *blank*, and at its end draw a vertical line equal to the lead of the screw. The diagonal line made by joining these two points shows the angle of incline of the grooves. This can be done more easily if both the circumference and the pitch are laid out to *ten times* their actual dimensions.

The diameters of the blanks are the *pitch diameter* of the finished thread and can be found in the Thread Tables, pages 47 and 55.

TO CORRECT PITCH DIAMETER TO MICROMETER READING

Tables on pages 31 and 32 will save many calculations. The decimal shown by the asterik gives the amount to add to the pitch diameter to find the micrometer reading over the wires if the P. D. is correct. For a 1-inch, 8-pitch American thread the P. D. is 0.91881 inch. With the best wire the table shows 0.108253 as the amount to add. The sum is 1.02711 as before. The other figures show the amounts to be added to the P. D. when wires of the other sizes designated are used.

For threads of other angles the following formulæ are used:

Whitworth 55 deg.—M = P. D.—0.960491 P + (3.1647 G)
British Asso. 47½ inches—M = P. D.—1.13633 P + (3.4829 G)
Lowenherz 53 deg. 8 min.—M = P. D.—P + (3.23594 G)
Acme—29 deg. M = P. D.—1.93334 P + (4.9938 G)

OPTICAL METHODS OF MEASURING THREADS

There are several makes of apparatus for optical measurement, both in this country and abroad. One method makes direct observations of the magnified screw thread, while the other projects an image of the thread against a greatly magnified chart and compares the outlines in this way. With the apparatus set by a screw of correct pitch diameter, the projected shadow not only shows the thread form but also whether the diameter is within the tolerance laid out on the chart. Some of these devices are very compact and allow of easy manipulation, so that screw threads can be

inspected very rapidly. A chart from a Hartness comparator, Fig. 16, shows how the magnified shadow is compared with the greatly enlarged chart and very slight errors detected at a glance.

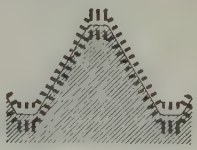


FIG. 16

THREAD FORMS, SIZES AND TOLERANCES

Great changes have taken place in screw threads during the past few years. The form of the Sellers, Franklin Institute or U. S. S. thread remains but modern practice pays close attention to pitch diameter instead of outside diameter and to tolerances of diameter, lead and angle, as all have a direct bearing on the fit. The old standards only considered form, outside diameters and corresponding pitches. So the U. S. S. and S. A. E. threads have given way to the American (National) Standard that includes all these dimensions. The tables that follow represent nearly ten years of work on the part of committees of the A. S. M. E., the S. A. E. and the National Screw Thread Commission. It is urged that we drop the term U. S. S. and S. A. E. thread and use American (National) Standard coarse or fine instead.

The main point to fix in mind is that both the outside and root diameters are relatively unimportant except that no thread should bear on either the crest or the root. The pitch diameter is very important, this corresponding to the pitch diameter of gears. The lead is also important as is the tooth spacing in gears. The combination of pitch diameter and lead has a great effect on the fit.

Thread measurement now deals principally with the pitch diameter and lead, the three-wire method superseding the two-wire, and the optical method also gaining in favor. The tables show the standard dimensions and tolerances for threads of different degrees of accuracy. It is urged that these tolerances be specified and used in all cases, selecting the kind of fit required by the work in hand. Tables of the new standards are included in this section beginning on page 39.

AMERICAN STANDARD SCREW THREADS FOR BOLTS, MACHINE SCREWS, NUTS AND COMMERCIALLY TAPPED HOLES

This section is from the report of a Committee on the Standardization and Unification of Screw Threads prepared in collaboration with the National Screw Thread Commission, the A.S.M.E. and the S.A.E. and approved by the American Engineering Standard Committee in May, 1924.

Terms Relating to Screw Threads

Screw Thread.—A ridge of uniform section in the form of a helix on the external or internal surface of a cylinder or cone.

External Thread.—An external thread is a thread on the outside of a member.

Internal Thread.—An internal thread is a thread on the inside of a member.

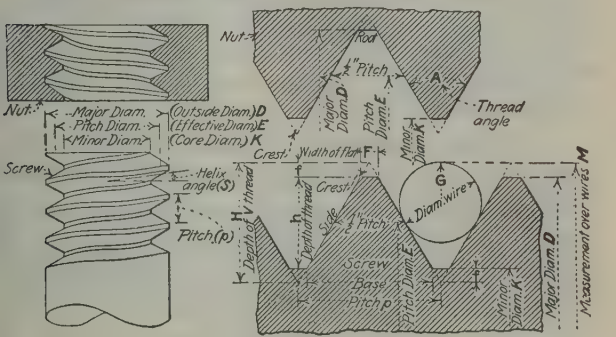


Fig. 17.—Screw Thread Parts

Major Diameter.—The largest diameter of a screw thread. The term "major diameter" replaces the term "outside diameter" as applied to the thread of a screw and also the term "full diameter" as applied to the thread of a nut.

Minor Diameter.—The smallest diameter of a screw thread. The term "minor diameter" replaces the terms "core diameter" and "root diameter" as applied to the thread of a screw and also the term "inside diameter" as applied to the thread of a nut.

Pitch Diameter.—On a straight screw thread the diameter of an imaginary cylinder, the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cylinder.

Pitch.—The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis.

$$\text{Pitch (in inches)} = \frac{1}{\text{Number of threads per inch}}.$$

Lead.—The distance a screw thread advances axially in one turn. On a single-thread screw, the lead and pitch are identical; on a double-thread screw, the lead is twice the pitch; on a triple-thread screw, the lead is three times the pitch, etc.

Angle of Thread.—The angle included between the sides of the thread measured in an axial plane.

Helix Angle.—The angle made by the helix of the thread at the pitch diameter with a plane perpendicular to the axis.

Crest.—The top surface joining the two sides of a thread.

Root.—The bottom surface joining the sides of two adjacent threads.

Side.—The surface of the thread which connects the crest with the root.

Axis of a Screw.—The longitudinal central line through the screw.

Depth of Thread.—The distance between the crest and the root of thread measured normally to the axis.

Length of Engagement.—The length of contact between two mating parts, measured axially.

Depth of Engagement.—The depth of thread contact of two mating parts, measured radially.

Terms Relating to Classification of Fits

Basic.—The theoretical or nominal standard size from which all variations are made.

Crest Clearance.—Defined on a screw form as the space between the crest of a thread and the root of its mating thread.

Allowance.—An intentional difference in the dimensions of mating parts. It is the minimum clearance or the maximum interference which is intended between mating parts.

Tolerance.—The amount of variation permitted in the size of a part.

Neutral Zone.—A positive allowance. (See Allowance.)

Limits.—The extreme permissible dimensions of a part.

Fit.—The relation between two mating parts with reference to ease of assembly; for example, wrench fit, close fit, medium fit, free fit. The quality of fit is dependent upon both the relative size and the quality of finish of the mating parts.

Finish.—The character of the surface on a screw thread.

Symbols

Dimensional Symbols.—For use in formulas for expressing relations of screw threads and for use on drawings and for similar purposes the following dimensional symbols should be used:

Major diameter	D
Corresponding radius	d
Pitch diameter	E
Corresponding radius	e
Minor diameter	K
Corresponding radius	k
Angle of thread	A
One-half angle of thread	a
Number of turns per inch	N
Number of threads per inch	n
Lead	$L = \frac{1}{N}$
Pitch or thread interval	$p = \frac{1}{n}$

Helix angle ..... s

Tangent of helix angle ..... $S = \frac{L}{3.14159 \times E}$

Width of basic flat at top crest or root ..... F
Depth of basic truncation ..... f
Depth of sharp V thread ..... H
Depth of American (National) form of thread ..... h

SYMBOLS FOR WIRE MEASUREMENTS

Measurement over wires ..... M
Diameter of wire ..... G
Corresponding radius ..... g

Identification Symbols.—These are for use on correspondence, rawings, shop and storeroom cards, specifications for parts, taps, ies, gages, etc., and on the tools and gages themselves.

The basis of the system is the initial letters of the series, preceded y the diameter in inches (or the screw number) and number of hreads per inch followed by the classification of fit all in Arabic haracters. If the thread is left-hand the symbol "L. H." shall ollow the number of threads. No symbol is used to distinguish ght-hand threads.

EXAMPLES:	MARK
American (National) Coarse-Thread System: To pecify a threaded part 1 inch in diameter, 8 hreads per inch, and Class 2 fit	1″–8–NC–2
American (National) Fine-Thread System: A hreaded part 1 inch in diameter, 14 threads per ch, left-hand thread, and Class 4 fit	1″–14–LH–NF–4
American (National) Form, Special Pitch: A hreaded part 1 inch in diameter, 12 threads per ch, and Class 3 fit	1″–12–N–3

NOTE: The number of threads per inch must be indicated in all ases, irrespective of whether it is the standard number of threads r that particular size of threaded part or special.

Form of Thread

The form of thread profile as specified herein, and known pre-iously as the United States Standard or Sellers' Profile, is adopted nd shall hereafter be known as the American (National) Form of hread.

Specifications.—The basic angle of thread between the sides of he thread measured in an axial plane shall be 60 degrees. The line ssecting this 60-degree angle shall be perpendicular to the axis the screw thread.

The basic width of flat at the root and crest of the thread form is ound as follows:

$$F = \tfrac{1}{8} \times p \text{ or } 0.125 \times p$$

The basic depth of the thread form is found as follows:

$$h = 0.649519 \times p = \frac{0.649519}{n}$$

where p = pitch in inches.
n = number of threads per inch.

Clearance in Nut at Minor Diameter.—A clearance shall b provided at the minor diameter of the nut by removing the threa form at the crest by an amount between one-sixth and one-fourt of the basic thread depth.

Clearance in Nut at Major Diameter.—A clearance at the majo diameter of the nut shall be provided by decreasing the depth o the truncation triangle any desired amount down to one-third o its theoretical value.

Thread Series Adopted

Two thread series are adopted—a coarse and a fine. The Coarse Thread Series is the present "United States Standard" supple mented in the sizes below ¼ inch by a part of the standard establishe by the American Society of Mechanical Engineers (A.S.M.E.) i 1907. The Fine-Thread Series (¼ to 1½ inches inclusive) is in acco dance with the present "Regular Screw-Thread Series of the S.A.E Standard for Screw-Threads" established by the Society of Auto motive Engineers (S.A.E.) in 1911, supplemented in sizes below inch by the Fine-Thread Series established by the American Societ of Mechanical Engineers (A.S.M.E.).

These two series are specified in Table 1.

Classification of Fits

Four distinct classes of screw-thread fits are established fo general use, as specified in the following brief outline. The example given under each class of fit are for the purpose of illustration only

Loose Fit (Class 1).—Recommended as a commercial standar for tapped holes in the numbered sizes only. May be used wit screws of other classes to obtain quality of fit desired.

Free Fit (Class 2).—Includes the great bulk of screw-thread wor of ordinary quality of finished and semi-finished bolts and nuts, et (Called "Medium Fit Regular" in the N.S.T.C. "Progres Report.")

Medium Fit (Class 3).—Includes the better grade of interchange able screw-thread work, such as automobile bolts and nuts (Calle "Medium Fit Special" in N.S.T.C. "Progress Report").

Close Fit (Class 4).—Includes screw-thread work requiring fine snug fit, somewhat closer than the medium fit, such as high grade aircraft parts, etc. In this class of fit selective assembly o parts may be required. It is not considered practicable as a com mercial standard for tapped holes of the numbered sizes.

A Second Method of Obtaining Medium Fit (Class 3)

A detailed examination of the tolerances given in Tables 3, and 5 will indicate that the same quality of fit as given by mediu fit screws and threaded holes can be obtained by using screws t

TABLE 1.—THE TWO-THREAD SERIES

1	2	3	4		5	6	
Sizes	Basic Major Diameter in Inches	Coarse Series, Threads per Inch	Helix Angle at Pitch Diameter		Fine Series, Threads per Inch	Helix Angle at Pitch Diameter	
			Degrees	Minutes		Degrees	Minutes
0	0.0600				80	4	23
1	0.0730	64	4	31	72	3	57
2	0.0860	56	4	22	64	3	45
3	0.0990	48	4	26	56	3	43
4	0.1120	40	4	25	48	3	51
5	0.1250	40	4	11	44	3	45
6	0.1380	32	4	50	40	3	44
8	0.1640	32	3	58	36	3	28
10	0.1900	24	4	39	32	3	21
12	0.2160	24	4	1	28	3	22
1/4	0.2500	20	4	11	28	2	52
5/16	0.3125	18	3	40	24	2	40
3/8	0.3750	16	3	24	24	2	11
7/16	0.4375	14	3	20	20	2	15
1/2	0.5000	13	3	7	20	1	57
9/16	0.5625	12	2	59	18	1	55
5/8	0.6250	11	2	56	18	1	43
3/4	0.7500	10	2	40	16	1	36
7/8	0.8750	9	2	31	14	1	34
1	1.0000	8	2	29	14	1	22
1 1/8	1.1250	7	2	31	12	1	25
1 1/4	1.2500	7	2	15	12	1	16
1 3/8	1.5000	6	2	11	12	1	3
1 3/4	1.7500	5	2	15	12[1]		
2	2.0000	4 1/2	2	11	12[1]		
2 1/4	2.2500	4 1/2	1	55	12[1]		
2 1/2	2.5000	4	1	57	12[1]		
2 3/4	2.7500	4	1	46	12[1]		
3	3.0000	4	1	36	10[1]		

[1] These pitches are suitable for work requiring short engagement where it is not practical to specify tolerances for all conditions. They are not, therefore, included in the succeeding tables.

close fit tolerances in holes made to free fit tolerances, or *vice versa*. The general adoption of this practice will reduce the variety of taps, gages, threaded parts, etc., required to be carried in stock. However, the combination of free and close fits should be used in place of medium fit only when the substitution is understood and agreed to by all parties concerned.

Conditions Requiring Special Fits.—In cases where looser fits are required than those given by the above-named classes, the use of the loose fit of the National Screw Thread Commission is recommended.

TABLE 2.—LOOSE FIT (CLASS 1)
Allowances and Tolerances for Nuts

1	2	3	4	5	
Threads per Inch	Allowances on Nut in Inches	Pitch Diameter Tolerances in Inches	Lead Tolerances[1,2] Inches	Tolerances in ½ Angle	
				Degrees	Minutes
80	0.0000	0.0024	0.0007	3	40
72	0.0000	0.0025	0.0007	3	26
64	0.0000	0.0026	0.0008	3	10
56	0.0000	0.0028	0.0008	3	0
48	0.0000	0.0031	0.0009	2	50
44	0.0000	0.0032	0.0009	2	41
40	0.0000	0.0034	0.0010	2	36
36	0.0000	0.0036	0.0010	2	28
32	0.0000	0.0038	0.0011	2	19
28	0.0000	0.0043	0.0012	2	18
24	0.0000	0.0046	0.0013	2	6

[1] The tolerances specified for pitch diameter in column 3 are cumulative and include all errors of lead and angle. The full tolerance on pitch diameter is therefore not available unless the lead and angle of the thread are perfect. Columns 4 and 5 give, for information, the error in lead (per length of thread engaged) and in angle, respectively, which can each be compensated for by half the tolerance on pitch diameter shown in column 3. If lead and angle error both exist to the amount tabulated, the pitch diameter of a bolt, for example, must be reduced by the full tolerance or it will not enter a basic nut or gage nor is the full tolerance available unless the gage be perfect. If no lead error existed on such a bolt, the angle error could be twice that given and *vice versa;* but these extreme conditions are not contemplated as being desirable. See Gages and Gaging of Screw Threads.

[2] Variation in lead between any two threads not farther apart than the length of engagement.

Special Pitch and Diameter Combinations.—In general, the tables given are intended for use with the two standard thread series only. The application of fine pitches to large diameters involves questions of workmanship which affect the grade of fit chosen.

When a pitch of thread is used with a diameter not called for in a standard thread series, it shall be defined as of "American (National) Form," but not as "American Standard."

GENERAL SPECIFICATIONS

The following general specifications will apply to all classes of fit specified in the body of the report. For special specifications applying to the loose fit class see the Commission's Report.

Uniform Minimum Nut.—The pitch diameter of the minimum threaded hole or nut corresponds to the basic size, variations being

TABLE 3.—FREE FIT (CLASS 2)
Allowances and Tolerances for Screws and Nuts

1	2	3	4	5	
Threads per Inch	Allowances in Inches	Pitch Diameter Tolerances[1] in Inches	Lead[1] Tolerances[2] in Inches	Tolerances in ½ Angle[1]	
				Degrees	Minutes
80	0.0000	0.0017	0.0005	2	36
72	0.0000	0.0018	0.0005	2	28
64	0.0000	0.0019	0.0005	2	19
56	0.0000	0.0020	0.0006	2	8
48	0.0000	0.0022	0.0006	2	1
44	0.0000	0.0023	0.0007	1	56
40	0.0000	0.0024	0.0007	1	50
36	0.0000	0.0025	0.0007	1	43
32	0.0000	0.0027	0.0008	1	39
28	0.0000	0.0031	0.0009	1	39
24	0.0000	0.0033	0.0010	1	31
20	0.0000	0.0036	0.0010	1	22
18	0.0000	0.0041	0.0012	1	25
16	0.0000	0.0045	0.0013	1	22
14	0.0000	0.0049	0.0014	1	19
13	0.0000	0.0052	0.0015	1	17
12	0.0000	0.0056	0.0016	1	17
11	0.0000	0.0059	0.0017	1	14
10	0.0000	0.0064	0.0018	1	13
9	0.0000	0.0070	0.0020	1	12
8	0.0000	0.0076	0.0022	1	10
7	0.0000	0.0085	0.0025	1	8
6	0.0000	0.0101	0.0029	1	9
5	0.0000	0.0116	0.0033	1	6
4½	0.0000	0.0127	0.0037	1	5
4	0.0000	0.0140	0.0040	1	4

[1] See note under Table 2, page 40.
[2] Variation in lead between any two threads not farther apart than the length of engagement.

permitted above the basic size. The major and minor diameters of the minimum nut are also uniform for all casses of fit.

Uniform Tap Drill Sizes.—The maximum and minimum minor diameters and the consequent minor diameter tolerances are the

TABLE 4.—MEDIUM FIT (CLASS 3)
Allowances and Tolerances for Screws and Nuts

1	2	3	4	5	
Threads per Inch	Allowances in Inches	Pitch Diameter Tolerances[1] in Inches	Lead[1] Tolerances[2] in Inches	Tolerances in ½ Angle[1]	
				Degrees	Minutes
80	0.0000	0.0013	0.0004	1	59
72	0.0000	0.0013	0.0004	1	47
64	0.0000	0.0014	0.0004	1	43
56	0.0000	0.0015	0.0004	1	36
48	0.0000	0.0016	0.0005	1	28
44	0.0000	0.0016	0.0005	1	23
40	0.0000	0.0017	0.0005	1	18
36	0.0000	0.0018	0.0005	1	14
32	0.0000	0.0019	0.0005	1	10
28	0.0000	0.0022	0.0006	1	11
24	0.0000	0.0024	0.0007	1	6
20	0.0000	0.0026	0.0008	1	0
18	0.0000	0.0030	0.0009	1	2
16	0.0000	0.0032	0.0009	0	59
14	0.0000	0.0036	0.0010	0	58
13	0.0000	0.0037	0.0011	0	55
12	0.0000	0.0040	0.0012	0	55
11	0.0000	0.0042	0.0012	0	53
10	0.0000	0.0045	0.0013	0	52
9	0.0000	0.0049	0.0014	0	51
8	0.0000	0.0054	0.0016	0	50
7	0.0000	0.0059	0.0017	0	47
6	0.0000	0.0071	0.0020	0	49
5	0.0000	0.0082	0.0024	0	47
4½	0.0000	0.0089	0.0026	0	46
4	0.0000	0.0097	0.0028	0	44

[1] See note under Table 2, page 40.
[2] Variation in lead between any two threads not farther apart than the length of engagment.

same for all nuts of a given size for all classes of fit. This permits uniform tap drill sizes for all classes of fit.

Uniform Major and Minor Diameter of Screws.—The maximum and minimum major and minor diameters are the same for all screws of a given size for all classes of fit herein tabulated.

TABLE 5.—CLOSE FIT (CLASS 4)
Allowances and Tolerances for Screws and Nuts

1	2	3	4	5	
Threads per Inch	Interference or Negative Allowances in Inches	Pitch Diameter Tolerances[1] in Inches	Lead[1] Tolerances[2] in Inches	Tolerances in ½ Angle[1]	
				Degrees	Minutes
80	0.0001	0 0006	0.0002	0	55
72	0.0001	0.0007	0.0002	0	58
64	0.0001	0.0007	0.0002	0	51
56	0.0002	0.0007	0.0002	0	45
48	0.0002	0.0008	0.0002	0	44
44	0.0002	0.0008	0.0002	0	40
40	0.0002	0.0009	0.0003	0	41
36	0.0002	0.0009	0.0003	0	37
32	0.0002	0.0010	0.0003	0	37
28	0.0002	0.0011	0.0003	0	35
24	0.0003	0.0012	0.0003	0	33
20	0.0003	0.0013	0.0004	0	30
18	0.0003	0.0015	0.0004	0	31
16	0.0004	0.0016	0.0005	0	29
14	0.0004	0.0018	0.0005	0	29
13	0.0004	0.0019	0.0005	0	28
12	0.0005	0.0020	0.0006	0	28
11	0.0005	0.0021	0.0006	0	26
10	0.0006	0.0023	0.0007	0	26
9	0.0006	0.0024	0.0007	0	25
8	0.0007	0.0027	0.0008	0	25
7	0.0008	0.0030	0.0009	0	24
6	0.0009	0.0036	0.0010	0	25
5	0.0010	0.0041	0.0012	0	23
4½	0.0011	0.0044	0.0013	0	23
4	0.0013	0.0048	0.0014	0	22

[1] See note under Table 2, page 40.

Length of Engagement.—The tolerances herein determined are based on a length of engagement not to exceed the nominal or major diameter of the screw. Where greater lengths of engagement are required, a corresponding increase in the accuracy of lead and thread form is necessary, which may be obtained by the provision of selection of more accurate threading tools, and the use of longer "go" gages.

Rounded Root Forms.—The crest clearances allowed are such as to permit rounded root forms in both nut and screw. These may be formed either by tools purposely rounded or rounded as a result of wear in use. For the limits of this permissible rounding see Tolerances, page 45.

DEFINITIONS

Loose Fit (Class 1).—This class of screw threads is, in this report recommended for use in tapped holes in the *numbered sizes only*. For such use it will be defined and specified as follows:

Minimum Nut is Basic.

Direction of Tolerance on Nut: The tolerance on the nut will be plus.

Tolerance Values: The tolerances for a nut of a given pitch will be as specified in Table 2.

Free Fit (Class 2).—This class of screw threads will be defined and specified as follows:

Minimum Nut is Basic.

Maximum Screw is Basic.

Direction of Tolerance on Nut: The tolerance on the nut will be plus.

Direction of Tolerance on Screw: The tolerance on the screw will be minus.

Zero Allowance: The allowance between the pitch diameter of the maximum screw and minimum nut will be zero for all pitches and all diameters.

Tolerance Values: The tolerances for a screw or nut of a given pitch will be specified in Table 3.

Medium Fit (Class 3).—This class of screw threads will be defined and specified as follows:

Minimum Nut is Basic.

Maximum Screw is Basic.

Direction of Tolerance on Nut: The tolerance on the nut will be plus.

Direction of Tolerance on Screw:[1] The tolerance on the screw will be minus.

Zero Allowance: The allowance between the pitch diameter of the maximum screw and the miminum nut will be zero for all pitches and all diameters.

Tolerance Values: The tolerances for a screw or nut of a given pitch will be specified in Table 4.

Close Fit (Class 4).—This class of screw threads will be defined and specified as follows:

Minimum Nut is Basic.

Maximum Screw is Above Basic: The major diameter and pitch diameter of the maximum screw will be above dimensions by the amount of the negative allowance (interference) specified in Table 5.

Direction of Tolerance on Nut: The tolerance on the nut will be plus.

Direction of Tolerance on Screw: The tolerance on the screw will be minus.

[1] The maximum minor diameter of the screw is above the basic minor diameter.

Allowance Values: The negative allowance (interference) provided between the pitch diameter of the minimum nut, which is basic, and that of the maximum screw, which is above basic, will be as specified in Table 5.

Tolerance Values: The tolerance for a screw or nut of a given pitch will be as specified in Table 5.

Tolerances

Tolerances Represent Extreme Variations.—The tolerances as hereinafter specified are for the classes of fit listed in the body of the report, and represent the extreme variations allowed on the work (see illustration below).

Pitch-Diameter Tolerances.—These are derived from the pitch of the thread instead of from the diameter. The method of derivation is explained on page 62.

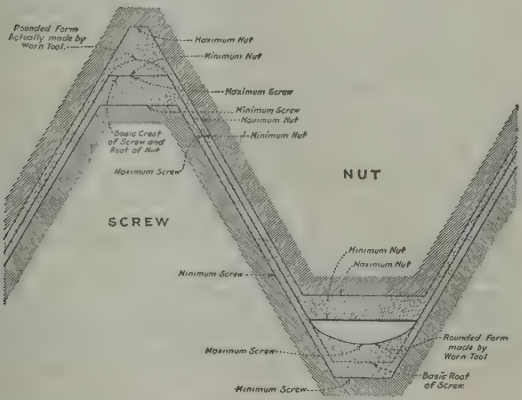


Fig. 18.—Illustrating Tolerances and Crest Clearances for Free and Medium Fits (Classes 2 and 3)

Pitch-Diameter Tolerances Include Lead and Angle Variations.—The relations between these quantities are expressed by columns 4 and 5 of Tables 2, 3, 4 and 5 and are explained by the note at the bottom of each table (see page 40).

These relations may be automatically insured by using a "go" gage of the length of engagement required, or by projecting an equivalent length of thread on a suitable chart, or by so projecting a single thread constrained for the required length of engagement, or by any other means which preserves the mathematical relation between variations in pitch diameter, lead and form.

Pitch-Diameter Tolerances on Screw Same as on Nut.—The pitch-diameter tolerances provided for a screw of a given class of fit will be the same as the pitch-diameter tolerances provided for the corresponding nut of the same class of fit.

Tolerances on Major Diameter of Screw Twice Pitch Diameter of Tolerances for Free Fit.—The allowable tolerances on the major diameter of screws of all classifications will be twice the tolerance value allowed on the pitch diameters of screws of the Free Fit (Class 2).

Tolerances on Minor Diameter of Screw.—The minimum minor diameter of a screw of a given pitch will be such as to result in a basic flat ($\frac{1}{8} \times p$) at the root.

The maximum minor diameter is that which would result from the use of a threading tool, set at the maximum pitch diameter, whose point has been worn or ground back from the basic outline by an amount equal to one-eighteenth of the basic depth of engagement ($\frac{1}{18} h$ or $0.03684\ p$). It is permissible that the resulting root line shall be rounded In no case, however, should the form be such as to cause the screw to be rejected on the minor diameter by a "go" ring rage, the minor diameter of which is equal to the minimum minor diameter of the nut.

Tolerances on Major Diameter of Nut.—The maximum major diameter of the nut of a given pitch will be such as to result in a flat one-third of the basic flat ($\frac{1}{12} \times p$).

The nominal minimum major diameter of the nut equals the basic major diameter. In practice a clearance is provided to facilitate manufacture by permitting a slight rounding or wear at the crest of the tap. In no case, however, should the outline resulting from a worn tap or cutting tool be such as to cause the nut to be rejected on the major diameter by a "go" plug gage made to basic form and dimensions at the crest.

Tolerances on Minor Diameter of Nut.—The tolerances on minor diameter of a nut of a given pitch will be one-sixth of the basic thread depth regardless of the class of fit being produced ($\frac{1}{6} h$ or $0.10825\ p$). The maximum and minimum minor diameters are determined by the conditions set forth on page 38, Par. 3. In the case of a punched hole the average diameter of the hole shall govern.

Coarse-Thread Series

The American Standard Coarse-thread Series, defined in Table 6, is recommended for use with free-fit (Class 2) tolerances, and medium-fit tolerances (Class 3). Its use with close-fit (Class 4) tolerances is also permissible, especially in producing the medium fit as described on page 38. It is recommended for use with the loose-fit tolerances (Class1), for nuts only in the numbered sizes.

The resulting dimensions of external and internal screw threads with these fits are shown in Tables 7, 8, 9, 10, 11, 12 and 13.

TABLE 6.—COARSE-THREAD SERIES—GENERAL DIMENSIONS[1]

1	2	3	4	5	6	7
Identification		Basic Diameters in Inches			Thread Data in Inches	
Sizes	Threads per Inch n	Major Diameter D	Pitch Diameter E	Minor Diameter K	Pitch[2] p	Basic Depth of Thread h
1	64	0.0730	0.0629	0.0527	0.0156250	0.01014
2	56	0.0860	0.0744	0.0628	0.0178571	0.01160
3	48	0.0990	0.0855	0.0719	0.0208333	0.01353
4	40	0.1120	0.0958	0.0795	0.0250000	0.01624
5	40	0.1250	0.1088	0.0925	0.0250000	0.01624
6	32	0.1380	0.1177	0.0974	0.0312500	0.02030
8	32	0.1640	0.1437	0.1234	0.0312500	0.02030
10	24	0.1900	0.1629	0.1359	0.0416667	0.02706
12	24	0.2160	0.1889	0.1619	0.0416667	0.02706
1/4	20	0.2500	0.2175	0.1850	0.0500000	0.03248
5/16	18	0.3125	0.2764	0.2403	0.0555556	0.03608
3/8	16	0.3750	0.3344	0.2938	0.0625000	0.04060
7/16	14	0.4375	0.3911	0.3447	0.0714286	0.04640
1/2	13	0.5000	0.4500	0.4001	0.0769231	0.04996
9/16	12	0.5625	0.5084	0.4542	0.0833333	0.05413
5/8	11	0.6250	0.5660	0.5069	0.0909091	0.05905
3/4	10	0.7500	0.6850	0.6201	0.1000000	0.06495
7/8	9	0.8750	0.8028	0.7307	0.1111111	0.07217
1	8	1.0000	0.9188	0.8376	0.1250000	0.08119
1 1/8	7	1.1250	1.0322	0.9394	0.1428571	0.09279
1 1/4	7	1.2500	1.1572	1.0644	0.1428571	0.09279
1 1/2	6	1.5000	1.3917	1.2835	0.1666667	0.10825
1 3/4	5	1.7500	1.6201	1.4902	0.2000000	0.12990
2	4 1/2	2.0000	1.8557	1.7113	0.2222222	0.14434
2 1/4	4 1/2	2.2500	2.1057	1.9613	0.2222222	0.14434
2 1/2	4	2.5000	2.3376	2.1752	0.2500000	0.16238
2 3/4	4	2.7500	2.5876	2.4252	0.2500000	0.16238
3	4	3.0000	2.8376	2.6752	0.2500000	0.16238

[1] The dimension of screw-thread gages and other important information on the gaging of screw threads will be found in the second report of this Committee entitled "Gages and Gaging of Screw Threads."

[2] This column is given to seven decimal places for computation purposes only.

TABLE 7.—COARSE-THREAD SERIES—FREE FIT (CLASS 2)—SCREWS

1	2	3	4	4a	5	6	7	8
		Major Diameter in Inches			Pitch Diameter in Inches			
Size	Threads per Inch	Maximum[1]	Semi-finished and Finished Bolts and Screws: Minimum	Threaded Parts of Unfinished Hot Rolled Material: Minimum	Maximum[1]	Tolerance[3]	Minimum	Maximum[2] Minor Diameter in Inches
1	64	0.0730	0.0692	0.0678	0.0629	0.0019	0.0610	0.0538
2	56	0.0860	0.0820	0.0804	0.0744	0.0020	0.0724	0.0641
3	48	0.0990	0.0946	0.0928	0.0855	0.0022	0.0833	0.0734
4	40	0.1120	0.1072	0.1052	0.0958	0.0024	0.0934	0.0813
5	40	0.1250	0.1202	0.1182	0.1088	0.0024	0.1064	0.0943
6	32	0.1380	0.1320	0.1304	0.1177	0.0027	0.1150	0.0997
8	32	0.1640	0.1586	0.1564	0.1437	0.0027	0.1410	0.1257
10	24	0.1900	0.1834	0.1808	0.1629	0.0033	0.1596	0.1389
12	24	0.2160	0.2094	0.2068	0.1889	0.0033	0.1856	0.1649
1/4	20	0.2500	0.2428	0.2398	0.2175	0.0036	0.2139	0.1887
5/16	18	0.3125	0.3043	0.3011	0.2764	0.0041	0.2723	0.2443
3/8	16	0.3750	0.3660	0.3624	0.3344	0.0045	0.3299	0.2983
7/16	14	0.4375	0.4277	0.4235	0.3911	0.0049	0.3862	0.3499
1/2	13	0.5000	0.4896	0.4852	0.4500	0.0052	0.4448	0.4056
9/16	12	0.5625	0.5513	0.5467	0.5084	0.0056	0.5028	0.4603
5/8	11	0.6250	0.6132	0.6080	0.5660	0.0059	0.5601	0.5135
3/4	10	0.7500	0.7372	0.7316	0.6850	0.0064	0.6786	0.6273
7/8	9	0.8750	0.8610	0.8550	0.8028	0.0070	0.7958	0.7387
1	8	1.0000	0.9848	0.9778	0.9188	0.0076	0.9112	0.8466
1 1/8	7	1.1250	1.1080	1.1002	1.0322	0.0085	1.0237	0.9497
1 1/4	7	1.2500	1.2330	1.2252	1.1572	0.0085	1.1487	1.0747
1 3/8	6	1.5000	1.4798	1.4710	1.3917	0.0101	1.3816	1.2955
1 1/2	5	1.7500	1.7268	1.7162	1.6201	0.0116	1.6085	1.5046
2	4 1/2	2.0000	1.9746	1.9632	1.8557	0.0127	1.8430	1.7274
2 1/4	4 1/2	2.2500	2.2246	2.2132	2.1057	0.0127	2.0930	1.9774
2 1/2	4	2.5000	2.4720	2.4592	2.3376	0.0140	2.3236	2.1933
2 3/4	4	2.7500	2.7220	2.7092	2.5876	0.0140	2.5736	2.4433
3	4	3.0000	2.9720	2.9592	2.8376	0.0140	2.8236	2.6933

[1] Basic diameter.

[2] Dimensions given are figured to intersection of the worn-tool arc with a center line through crest and root. Minimum flat at root equals $\frac{1}{8} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

NOTE.—For "Coarse-Thread Series—Loose Fit (Class 1)—Nuts" see Table 21, page 62.

TABLE 8.—COARSE-THREAD SERIES—FREE FIT (CLASS 2)—NUTS

1	2	3	6	7	8	9	10	11
Size	Threads per Inch	Minimum[1,2] Major Diameter in Inches	Pitch Diameter in Inches			Minor Diameter in Inches		
			Minimum[1]	Tolerance[3]	Maximum	Minimum	Tolerance	Maximum
1	64	0.0730	0.0629	0.0019	0.0648	0.0561	0.0017	0.0578
2	56	0.0860	0.0744	0.0020	0.0764	0.0667	0.0019	0.0686
3	48	0.0990	0.0855	0.0022	0.0877	0.0764	0.0023	0.0787
4	40	0.1120	0.0958	0.0024	0.0982	0.0849	0.0027	0.0876
5	40	0.1250	0.1088	0.0024	0.1112	0.0979	0.0027	0.1006
6	32	0.1380	0.1177	0.0027	0.1204	0.1042	0.0034	0.1076
8	32	0.1640	0.1437	0.0027	0.1464	0.1302	0.0034	0.1336
10	24	0.1900	0.1629	0.0033	0.1662	0.1449	0.0045	0.1494
12	24	0.2160	0.1889	0.0033	0.1922	0.1709	0.0045	0.1754
1/4	20	0.2500	0.2175	0.0036	0.2211	0.1959	0.0054	0.2013
5/16	18	0.3125	0.2764	0.0041	0.2805	0.2524	0.0060	0.2584
3/8	16	0.3750	0.3344	0.0045	0.3389	0.3073	0.0068	0.3141
7/16	14	0.4375	0.3911	0.0049	0.3960	0.3602	0.0077	0.3679
1/2	13	0.5000	0.4500	0.0052	0.4552	0.4167	0.0084	0.4251
9/16	12	0.5625	0.5084	0.0056	0.5140	0.4723	0.0090	0.4813
5/8	11	0.6250	0.5660	0.0059	0.5719	0.5266	0.0098	0.5364
3/4	10	0.7500	0.6850	0.0064	0.6914	0.6417	0.0109	0.6526
7/8	9	0.8750	0.8028	0.0070	0.8098	0.7547	0.0120	0.7667
1	8	1.0000	0.9188	0.0076	0.9264	0.8647	0.0135	0.8782
1 1/8	7	1.1250	1.0322	0.0085	1.0407	0.9704	0.0154	0.9858
1 1/4	7	1.2500	1.1572	0.0085	1.1657	1.0954	0.0154	1.1108
1 3/8	6	1.5000	1.3917	0.0101	1.4018	1.3196	0.0180	1.3376
1 1/4	5	1.7500	1.6201	0.0116	1.6317	1.5335	0.0216	1.5551
2	4 1/2	2.0000	1.8557	0.0127	1.8684	1.7594	0.0241	1.7835
2 1/4	4 1/2	2.2500	2.1057	0.0127	2.1184	2.0094	0.0241	2.0335
2 1/2	4	2.5000	2.3376	0.0140	2.3516	2.2294	0.0270	2.2564
2 3/4	4	2.7500	2.5876	0.0140	2.6016	2.4794	0.0270	2.5064
3	4	3.0000	2.8376	0.0140	2.8516	2.7294	0.0270	2.7564

[1] Basic diameter.

[2] Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\frac{1}{8} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

TABLE 9.—COARSE-THREAD SERIES—MEDIUM FIT (CLASS 3)—SCREWS

1	2	3	4	5	6	7	8	9
Size	Threads per Inch	Major Diameter in Inches			Pitch Diameter in Inches			Maximum[2] Minor Diameter in Inches
		Maximum[1]	Tolerance	Minimum	Maximum[1]	Tolerance[3]	Minimum	
1	64	0.0730	0.0038	0.0692	0.0629	0.0014	0.0615	0.0538
2	56	0.0860	0.0040	0.0820	0.0744	0.0015	0.0729	0.0641
3	48	0.0990	0.0044	0.0946	0.0855	0.0016	0.0839	0.0734
4	40	0.1120	0.0048	0.1072	0.0958	0.0017	0.0941	0.0813
5	40	0.1250	0.0048	0.1202	0.1088	0.0017	0.1071	0.0943
6	32	0.1380	0.0054	0.1326	0.1177	0.0019	0.1158	0.0997
8	32	0.1640	0.0054	0.1586	0.1437	0.0019	0.1418	0.1257
10	24	0.1900	0.0066	0.1834	0.1629	0.0024	0.1605	0.1389
12	24	0.2160	0.0066	0.2094	0.1889	0.0024	0.1865	0.1649
1/4	20	0.2500	0.0072	0.2428	0.2175	0.0026	0.2149	0.1887
5/16	18	0.3125	0.0082	0.3043	0.2764	0.0030	0.2734	0.2443
3/8	16	0.3750	0.0090	0.3660	0.3344	0.0032	0.3312	0.2983
7/16	14	0.4375	0.0098	0.4277	0.3911	0.0036	0.3875	0.3499
1/2	13	0.5000	0.0104	0.4896	0.4500	0.0037	0.4463	0.4056
9/16	12	0.5625	0.0112	0.5513	0.5084	0.0040	0.5044	0.4603
5/8	11	0.6250	0.0118	0.6132	0.5660	0.0042	0.5618	0.5135
3/4	10	0.7500	0.0128	0.7372	0.6850	0.0045	0.6805	0.6273
7/8	9	0.8750	0.0140	0.8610	0.8028	0.0049	0.7979	0.7387
1	8	1.0000	0.0152	0.9848	0.9188	0.0054	0.9134	0.8466
1 1/8	7	1.1250	0.0170	1.1080	1.0322	0.0059	1.0263	0.9497
1 1/4	7	1.2500	0.0170	1.2330	1.1572	0.0059	1.1513	1.0747
1 3/8	6	1.5000	0.0202	1.4798	1.3917	0.0071	1.3846	1.2955
1 3/4	5	1.7500	0.0232	1.7268	1.6201	0.0082	1.6119	1.5046
2	4 1/2	2.0000	0.0254	1.9746	1.8557	0.0089	1.8468	1.7274
2 1/4	4 1/2	2.2500	0.0254	2.2246	2.1057	0.0089	2.0968	1.9774
2 1/2	4	2.5000	0.0280	2.4720	2.3376	0.0097	2.3279	2.1933
2 3/4	4	2.7500	0.0280	2.7220	2.5876	0.0097	2.5779	2.4433
3	4	3.0000	0.0280	2.9720	2.8376	0.0097	2.8279	2.6933

[1] Basic diameter.

[2] Dimensions given are figured to the intersection of the worn-tool arc with a center line through crest and root. Minimum flat at root equals $\frac{1}{8} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

TABLE 10.—COARSE-THREAD SERIES—MEDIUM FIT (CLASS 3)—NUTS

1	2	3	6	7	8	9	10	11
Size	Threads per Inch	Minimum[1] Major Diameter[2] in Inches	Pitch Diameter in Inches			Minor Diameter in Inches		
			Minimum[1]	Tolerance[3]	Maximum	Minimum	Tolerance	Maximum
1	64	0.0730	0.0629	0.0014	0.0643	0.0561	0.0017	0.0578
2	56	0.0860	0.0744	0.0015	0.0759	0.0667	0.0019	0.0686
3	48	0.0990	0.0855	0.0016	0.0871	0.0764	0.0023	0.0787
4	40	0.1120	0.0958	0.0017	0.0975	0.0849	0.0027	0.0876
5	40	0.1250	0.1088	0.0017	0.1105	0.0979	0.0027	0.1006
6	32	0.1380	0.1177	0.0019	0.1196	0.1042	0.0034	0.1076
8	32	0.1640	0.1437	0.0019	0.1456	0.1302	0.0034	0.1336
10	24	0.1900	0.1629	0.0024	0.1653	0.1449	0.0045	0.1494
12	24	0.2160	0.1889	0.0024	0.1913	0.1709	0.0045	0.1754
1/4	24	0.2500	0.2175	0.0026	0.2201	0.1959	0.0054	0.2013
5/16	18	0.3125	0.2764	0.0030	0.2794	0.2524	0.0060	0.2584
3/8	16	0.3750	0.3344	0.0032	0.3376	0.3073	0.0068	0.3141
7/16	14	0.4375	0.3911	0.0036	0.3947	0.3602	0.0077	0.3679
1/2	13	0.5000	0.4500	0.0037	0.4537	0.4167	0.0084	0.4251
9/16	12	0.5625	0.5084	0.0040	0.5124	0.4723	0.0090	0.4813
5/8	11	0.6250	0.5660	0.0042	0.5702	0.5266	0.0098	0.5364
3/4	10	0.7500	0.6850	0.0045	0.6895	0.6417	0.0109	0.6526
7/8	9	0.8750	0.8028	0.0049	0.8077	0.7547	0.0120	0.7667
1	8	1.0000	0.9188	0.0054	0.9242	0.8647	0.0135	0.8782
1 1/8	7	1.1250	1.0322	0.0059	1.0381	0.9704	0.0154	0.9858
1 1/4	7	1.2500	1.1572	0.0059	1.1631	1.0954	0.0154	1.1108
1 1/2	6	1.5000	1.3917	0.0071	1.3988	1.3196	0.0180	1.3376
1 3/4	5	1.7500	1.6201	0.0082	1.6283	1.5335	0.0216	1.5551
2	4 1/2	2.0000	1.8557	0.0089	1.8646	1.7594	0.0241	1.7835
2 1/4	4 1/2	2.2500	2.1057	0.0089	2.1146	2.0094	0.0241	2.0335
2 1/2	4	2.5000	2.3376	0.0097	2.3473	2.2294	0.0270	2.2564
2 3/4	4	2.7500	2.5876	0.0097	2.5973	2.4794	0.0270	2.5064
3	4	3.0000	2.8376	0.0097	2.8473	2.7294	0.0270	2.7564

[1] Basic diameter.

[2] Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\frac{p}{4} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

TABLE 11.—COARSE-THREAD SERIES—CLOSE FIT (CLASS 4)—SCREWS

1	2	3	4	5	6	7	8	9
Size	Threads per Inch	Major Diameter in Inches			Pitch Diameter in Inches			Maximum Minor Diameter in Inches
		Maximum	Tolerance	Minimum	Maximum	Tolerance[1]	Minimum	
1	64	0.0730	0.0038	0.0692	0.0630	0.0007	0.0623	0.058
2	56	0.0860	0.0040	0.0820	0.0746	0.0007	0.0739	0.069
3	48	0.0990	0.0041	0.0949	0.0857	0.0008	0.0849	0.079
4	40	0.1120	0.0048	0.1072	0.0960	0.0030	0.0951	0.085
5	40	0.1250	0.0048	0.1202	0.1090	0.0030	0.1081	0.098
6	32	0.1380	0.0054	0.1326	0.1179	0.0010	0.1169	0.098
8	32	0.1640	0.0054	0.1586	0.1439	0.0010	0.1429	0.125
10	24	0.1900	0.0066	0.1834	0.1632	0.0012	0.1620	0.138
12	24	0.2160	0.0066	0.2094	0.1892	0.0012	0.1880	0.164
1/4	20	0.2500	0.0072	0.2428	0.2178	0.0013	0.2165	0.188
5/16	18	0.3125	0.0082	0.3043	0.2767	0.0015	0.2752	0.244
3/8	16	0.3750	0.0090	0.3660	0.3348	0.0020	0.3332	0.298
7/16	14	0.4375	0.0098	0.4277	0.3915	0.0018	0.3897	0.349
1/2	13	0.5000	0.0104	0.4896	0.4504	0.0019	0.4485	0.405
9/16	12	0.5625	0.0112	0.5513	0.5089	0.0020	0.5069	0.460
5/8	11	0.6250	0.0118	0.6132	0.5665	0.0021	0.5644	0.513
3/4	10	0.7500	0.0128	0.7372	0.6856	0.0023	0.6833	0.627
7/8	9	0.8750	0.0140	0.8610	0.8034	0.0024	0.8010	0.738
1	8	1.0000	0.0152	0.9848	0.9195	0.0027	0.9168	0.846
1 1/8	7	1.1250	0.0170	1.1080	1.0330	0.0030	1.0300	0.949
1 1/4	7	1.2500	0.0170	1.2330	1.1580	0.0030	1.1550	1.074
1 3/8	6	1.3000	0.0202	1.4798	1.3926	0.0036	1.3890	1.295
1 1/2	5	1.7500	0.0232	1.7268	1.6211	0.0041	1.6170	1.504
2	4 1/2	2.0000	0.0254	1.9746	1.8568	0.0044	1.8524	1.727
2 1/4	4 1/2	2.2500	0.0254	2.2246	2.1068	0.0044	2.1024	1.977
2 1/2	4	2.5000	0.0280	2.4720	2.3389	0.0048	2.3341	2.193
2 3/4	4	2.7500	0.0280	2.7220	2.5889	0.0048	2.5841	2.443
3	4	3.0000	0.0280	2.9720	2.8389	0.0048	2.8341	2.693

[1] Basic diameter.

[2] Dimensions given are figured to the intersection of the worn-tool ar with a center line through crest and root. Minimum flat at root equal $\frac{1}{8} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and als include errors of lead and angle.

TABLE 12.—COARSE-THREAD SERIES—CLOSE FIT (CLASS 4)—NUTS

1	2	3	6	7	8	9	10	11
Size	Threads per Inch	Minimum[1] Major Diameter[2] in Inches	Pitch Diameter in Inches			Minor Diameter in Inches		
			Minimum[1]	Tolerance[3]	Maximum	Minimum	Tolerance	Maximum
1/4	20	0.2500	0.2175	0.0013	0.2188	0.1959	0.0054	0.2013
5/16	18	0.3125	0.2764	0.0015	0.2779	0.2524	0.0060	0.2584
3/8	16	0.3750	0.3344	0.0016	0.3360	0.3073	0.0068	0.3141
7/16	14	0.4375	0.3911	0.0018	0.3929	0.3602	0.0077	0.3679
1/2	13	0.5000	0.4500	0.0019	0.4519	0.4167	0.0084	0.4251
9/16	12	0.5625	0.5084	0.0020	0.5104	0.4723	0.0090	0.4813
5/8	11	0.6250	0.5660	0.0021	0.5681	0.5266	0.0098	0.5364
3/4	10	0.7500	0.6850	0.0023	0.6873	0.6417	0.0109	0.6526
7/8	9	0.8750	0.8028	0.0024	0.8052	0.7547	0.0120	0.7667
1	8	1.0000	0.9188	0.0027	0.9215	0.8647	0.0135	0.8782
1 1/8	7	1.1250	1.0322	0.0030	1.0352	0.9704	0.0154	0.9858
1 1/4	7	1.2500	1.1572	0.0030	1.1602	1.0954	0.0154	1.1108
1 3/8	6	1.5000	1.3017	0.0036	1.3053	1.3196	0.0180	1.3376
1 3/4	5	1.7500	1.6201	0.0041	1.6242	1.5335	0.0216	1.5551
2	4 1/2	2.0000	1.8557	0.0044	1.8601	1.7594	0.0241	1.7835
2 1/4	4 1/2	2.2500	2.1057	0.0044	2.1101	2.0094	0.0241	2.0335
2 1/2	4	2.5000	2.3376	0.0048	2.3424	2.2294	0.0270	2.2564
2 3/4	4	2.7500	2.5876	0.0048	2.5924	2.4794	0.0270	2.5064
3	4	3.0000	2.8376	0.0048	2.8424	2.7294	0.0270	2.7564

[1] Basic diameter.

[2] Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\frac{1}{4} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

Fine-Thread Series

The American Standard Fine-Thread Series, defined in Table 14, is recommended for use with medium-fit (Class 3) tolerances and close-fit (Class 4) tolerances. Its use with free-fit (Class 2) tolerances is also permissible, especially in producing (Class 3) tolerances, as described under "Classification of Fits," on page 38.

The resulting dimensions of external and internal screw threads with these fits and tolerances are shown in Tables 14, 15, 16, 17, 18, 19, and 20.

TABLE 13.—FINE-THREAD SERIES—GENERAL DIMENSIONS[1]

1	2	3	4	5	6	7
Identification		Basic Diameters in Inches			Thread Data in Inches	
Sizes	Threads per Inch	Major Diameter D	Pitch Diameter E	Minor Diameter K	Pitch[2] p	Basic Depth of Thread h
0	80	0.0600	0.0519	0.0438	0.0125000	0.00812
1	72	0.0730	0.0640	0.0550	0.0138889	0.00902
2	64	0.0860	0.0759	0.0657	0.0156250	0.01014
3	56	0.0990	0.0874	0.0758	0.0178571	0.01160
4	48	0.1120	0.0985	0.0849	0.0208333	0.01353
5	44	0.1250	0.1102	0.0955	0.0227273	0.01476
6	40	0.1380	0.1218	0.1055	0.0250000	0.01624
8	36	0.1640	0.1460	0.1279	0.0277778	0.01804
10	32	0.1900	0.1697	0.1494	0.0312500	0.02030
12	28	0.2160	0.1928	0.1696	0.0357143	0.02319
1/4	28	0.2500	0.2268	0.2036	0.0357143	0.02319
5/16	24	0.3125	0.2854	0.2584	0.0416667	0.02706
3/8	24	0.3750	0.3479	0.3209	0.0416667	0.02706
7/16	20	0.4375	0.4050	0.3725	0.0500000	0.03248
1/2	20	0.5000	0.4675	0.4350	0.0500000	0.03248
9/16	18	0.5625	0.5264	0.4903	0.0555556	0.03608
5/8	18	0.6250	0.5889	0.5528	0.0555556	0.03608
3/4	16	0.7500	0.7094	0.6688	0.0625000	0.04060
7/8	14	0.8750	0.8286	0.7822	0.0714286	0.04640
1	14	1.0000	0.9536	0.9072	0.0714286	0.04640
1 1/8	12	1.1250	1.0709	1.0167	0.0833333	0.05413
1 1/4	12	1.2500	1.1959	1.1417	0.0833333	0.05413
1 1/2	12	1.5000	1.4459	1.3917	0.0833333	0.05413

[1]The dimensions of screw-thread gages and other important information on the gaging of screw threads will be found in the second report of this Committee entitled "Gages and Gaging of Screw Threads."

[2]This column is given to seven decimal places for computation purposes only.

TABLE 14.—FINE-THREAD SERIES—LOOSE FIT (CLASS 1)—NUTS[1]

1	2	3	6	7	8	9	10	11
Size	Threads per Inch	Minimum,[2] Major Diameter[3] in Inches	Pitch Diameter in Inches			Minor Diameter in Inches		
			Minimum[2]	Tolerance[4]	Maximum	Minimum	Tolerance	Maximum
0	80	0.060	0.0519	0.0024	0.0543	0.0465	0.0013	0.0478
1	72	0.073	0.0640	0.0025	0.0665	0.0580	0.0015	0.0595
2	64	0.086	0.0759	0.0026	0.0785	0.0691	0.0017	0.0708
3	56	0.099	0.0874	0.0028	0.0902	0.0797	0.0019	0.0816
4	48	0.112	0.0985	0.0031	0.1016	0.0894	0.0023	0.0917
5	44	0.125	0.1102	0.0032	0.1134	0.1004	0.0025	0.1029
6	40	0.138	0.1218	0.0034	0.1252	0.1109	0.0027	0.1136
8	36	0.164	0.1460	0.0036	0.1496	0.1339	0.0030	0.1369
10	32	0.190	0.1697	0.0038	0.1735	0.1562	0.0034	0.1596
12	28	0.216	0.1928	0.0043	0.1971	0.1773	0.0039	0.1812

[1] This fit is recommended for nuts only, in the numbered sizes.

[2] Basic diameter.

[3] Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\frac{1}{4} \times p$.

[4] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

TABLE 15.—FINE-THREAD SERIES—FREE FIT (CLASS 2)—SCREWS

1	2	3	4	5	6	7	8	9
Sizes	Threads per Inch	Major Diameter in Inches			Pitch Diameter in Inches			Maximum[2] Minor Diameter in Inches
		Maximum[1]	Tolerance	Minimum	Maximum[1]	Tolerance[3]	Minimum	
0	80	0.060	0.0034	0.0566	0.0519	0.0017	0.0502	0.0447
1	72	0.073	0.0036	0.0694	0.0640	0.0018	0.0622	0.0560
2	64	0.086	0.0038	0.0822	0.0759	0.0019	0.0740	0.0668
3	56	0.099	0.0040	0.0950	0.0874	0.0020	0.0854	0.0771
4	48	0.112	0.0044	0.1076	0.0985	0.0022	0.0963	0.0864
5	44	0.125	0.0046	0.1204	0.1102	0.0023	0.1079	0.0971
6	40	0.138	0.0048	0.1332	0.1218	0.0024	0.1194	0.1073
8	36	0.164	0.0050	0.1590	0.1460	0.0025	0.1435	0.1299
10	32	0.190	0.0054	0.1846	0.1697	0.0027	0.1670	0.1517
12	28	0.216	0.0062	0.2098	0.1928	0.0031	0.1897	0.1722
$\frac{1}{4}$	28	0.2500	0.0062	0.2438	0.2268	0.0031	0.2237	0.2062
$\frac{5}{16}$	24	0.3125	0.0066	0.3059	0.2854	0.0033	0.2821	0.2614
$\frac{3}{8}$	24	0.3750	0.0066	0.3684	0.3479	0.0033	0.3446	0.3239
$\frac{7}{16}$	20	0.4375	0.0072	0.4303	0.4050	0.0036	0.4014	0.3762
$\frac{1}{2}$	20	0.5000	0.0072	0.4928	0.4675	0.0036	0.4639	0.4387
$\frac{9}{16}$	18	0.5625	0.0082	0.5543	0.5264	0.0041	0.5223	0.4943
$\frac{5}{8}$	18	0.6250	0.0082	0.6168	0.5889	0.0041	0.5848	0.5568
$\frac{3}{4}$	16	0.7500	0.0090	0.7410	0.7094	0.0045	0.7049	0.6733
$\frac{7}{8}$	14	0.8750	0.0098	0.8652	0.8286	0.0049	0.8237	0.7874
1	14	1.0000	0.0098	0.9902	0.9536	0.0049	0.9487	0.9124
$1\frac{1}{8}$	12	1.1250	0.0112	1.1138	1.0709	0.0056	1.0653	1.0228
$1\frac{1}{4}$	12	1.2500	0.0112	1.2388	1.1959	0.0056	1.1903	1.1478
$1\frac{1}{2}$	12	1.5000	0.0112	1.4888	1.4459	0.0056	1.4403	1.3978

[1] Basic diameter.

[2] Dimensions given are figured to the intersection of the worn-tool arc with a center line through crest and root. Minimum flat at root equals $\frac{1}{8} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

TABLE 16.—FINE-THREAD SERIES—FREE FIT (CLASS 2)—NUTS

1	2	3	6	7	8	9	10	11
Size	Threads per Inch	Minimum[1] Major Diameter[2] in Inches	Pitch Diameter in Inches			Minor Diameter in Inches		
			Minimum[1]	Tolerance[3]	Maximum	Minimum	Tolerance	Maximum
0	80	0.0600	0.0519	0.0017	0.0536	0.0465	0.0013	0.0478
1	72	0.0730	0.0640	0.0018	0.0658	0.0580	0.0015	0.0595
2	64	0.0860	0.0759	0.0019	0.0778	0.0691	0.0017	0.0708
3	56	0.0990	0.0874	0.0020	0.0894	0.0797	0.0019	0.0816
4	48	0.1120	0.0985	0.0022	0.1007	0.0894	0.0023	0.0917
5	44	0.1250	0.1102	0.0023	0.1125	0.1004	0.0025	0.1029
6	40	0.1380	0.1218	0.0024	0.1242	0.1109	0.0027	0.1136
8	36	0.1640	0.1460	0.0025	0.1485	0.1339	0.0030	0.1369
10	32	0.1900	0.1697	0.0027	0.1724	0.1562	0.0034	0.1596
12	28	0.2160	0.1928	0.0031	0.1959	0.1773	0.0039	0.1812
1/4	28	0.2500	0.2268	0.0031	0.2299	0.2113	0.0039	0.2152
5/16	24	0.3125	0.2854	0.0033	0.2887	0.2674	0.0045	0.2719
3/8	24	0.3750	0.3479	0.0033	0.3512	0.3209	0.0045	0.3344
7/16	20	0.4375	0.4050	0.0036	0.4086	0.3834	0.0054	0.3888
1/2	20	0.5000	0.4675	0.0036	0.4711	0.4459	0.0054	0.4513
9/16	18	0.5625	0.5264	0.0041	0.5305	0.5024	0.0060	0.5084
5/8	18	0.6250	0.5889	0.0041	0.5930	0.5649	0.0060	0.5709
3/4	16	0.7500	0.7094	0.0045	0.7139	0.6823	0.0068	0.6891
7/8	14	0.8750	0.8286	0.0049	0.8335	0.7977	0.0077	0.8054
1	14	1.0000	0.9536	0.0049	0.9585	0.9227	0.0077	0.9304
1 1/4	12	1.1250	1.0709	0.0056	1.0765	1.0348	0.0090	1.0438
1 1/4	12	1.2500	1.1959	0.0056	1.2015	1.1508	0.0090	1.1688
1 1/2	12	1.5000	1.4459	0.0056	1.4515	1.4098	0.0090	1.4188

[1] Basic diameter.

[2] Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\frac{1}{4} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

TABLE 17.—FINE-THREAD SERIES—MEDIUM FIT (CLASS 3)—SCREWS

1	2	3	4	5	6	7	8	9
Size	Threads per Inch	Major Diameter in Inches			Pitch Diameter in Inches			Maximum[2] Minor Diameter in Inches
		Maximum[1]	Tolerance	Minimum	Maximum[1]	Tolerance[2]	Minimum	
0	80	0.0600	0.0034	0.0566	0.0519	0.0013	0.0506	0.0447
1	72	0.0730	0.0036	0.0694	0.0640	0.0013	0.0627	0.0560
2	64	0.0860	0.0038	0.0822	0.0759	0.0014	0.0745	0.0668
3	56	0.0990	0.0040	0.0950	0.0874	0.0015	0.0859	0.0771
4	48	0.1120	0.0044	0.1076	0.0985	0.0016	0.0969	0.0864
5	44	0.1250	0.0046	0.1204	0.1102	0.0016	0.1086	0.0971
6	40	0.1380	0.0048	0.1332	0.1218	0.0017	0.1201	0.1073
8	36	0.1640	0.0050	0.1590	0.1460	0.0018	0.1442	0.1299
10	32	0.1900	0.0054	0.1846	0.1697	0.0019	0.1678	0.1517
12	28	0.2160	0.0062	0.2098	0.1928	0.0022	0.1906	0.1722
1/4	28	0.2500	0.0062	0.2438	0.2268	0.0022	0.2246	0.2062
5/16	24	0.3125	0.0066	0.3059	0.2854	0.0024	0.2830	0.2614
3/8	24	0.3750	0.0066	0.3684	0.3479	0.0024	0.3455	0.3239
7/16	20	0.4375	0.0072	0.4303	0.4050	0.0026	0.4024	0.3762
1/2	20	0.5000	0.0072	0.4928	0.4675	0.0026	0.4649	0.4387
9/16	18	0.5625	0.0082	0.5543	0.5264	0.0030	0.5234	0.4943
5/8	18	0.6250	0.0082	0.6168	0.5889	0.0030	0.5859	0.5568
3/4	16	0.7500	0.0090	0.7410	0.7094	0.0032	0.7062	0.6733
7/8	14	0.8750	0.0098	0.8652	0.8286	0.0036	0.8250	0.7874
1	14	1.0000	0.0098	0.9902	0.9536	0.0036	0.9500	0.9124
1 1/8	12	1.1250	0.0112	1.1138	1.0709	0.0040	1.0669	1.0228
1 1/4	12	1.2500	0.0112	1.2388	1.1959	0.0040	1.1919	1.1478
1 1/2	12	1.5000	0.0112	1.4888	1.4459	0.0040	1.4419	1.3978

[1] Basic diameter.

[2] Dimensions given are figured to the intersection of the worn-tool arc with a center line through crest and root. Minimum flat at root equals $\frac{1}{24} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

TABLE 18.—FINE-THREAD SERIES—MEDIUM FIT (CLASS 3)—NUTS

1	2	3	6	7	8	9	10	11
Size	Threads per Inch	Minimum[1] Major Diameter[2] in Inches	Pitch Diameter in Inches			Minor Diameter in Inches		
			Minimum[1]	Tolerance[3]	Maximum	Minimum	Tolerance	Maximum
0	80	0.0600	0.0519	0.0013	0.0532	0.0465	0.0013	0.0478
1	72	0.0730	0.0640	0.0013	0.0653	0.0580	0.0015	0.0595
2	64	0.0860	0.0759	0.0014	0.0773	0.0691	0.0017	0.0708
3	56	0.0990	0.0874	0.0015	0.0889	0.0797	0.0019	0.0816
4	48	0.1120	0.0985	0.0016	0.1001	0.0894	0.0023	0.0917
5	44	0.1250	0.1102	0.0016	0.1118	0.1004	0.0025	0.1029
6	40	0.1380	0.1218	0.0017	0.1235	0.1109	0.0027	0.1136
8	36	0.1640	0.1460	0.0018	0.1478	0.1339	0.0030	0.1369
10	32	0.1900	0.1697	0.0019	0.1716	0.1562	0.0034	0.1596
12	28	0.2160	0.1928	0.0022	0.1950	0.1773	0.0039	0.1812
1/4	28	0.2500	0.2268	0.0022	0.2290	0.2113	0.0039	0.2152
5/16	24	0.3125	0.2854	0.0024	0.2878	0.2674	0.0045	0.2719
3/8	24	0.3750	0.3479	0.0024	0.3503	0.3299	0.0045	0.3344
7/16	20	0.4375	0.4050	0.0026	0.4076	0.3834	0.0054	0.3888
1/2	20	0.5000	0.4675	0.0026	0.4701	0.4459	0.0054	0.4513
9/16	18	0.5625	0.5264	0.0030	0.5294	0.5024	0.0060	0.5084
5/8	18	0.6250	0.5889	0.0030	0.5919	0.5649	0.0060	0.5709
3/4	16	0.7500	0.7094	0.0032	0.7126	0.6823	0.0068	0.6891
7/8	14	0.8750	0.8286	0.0036	0.8322	0.7977	0.0077	0.8054
1	14	1.0000	0.9536	0.0036	0.9572	0.9227	0.0077	0.9304
1 1/8	12	1.1250	1.0709	0.0040	1.0749	1.0348	0.0090	1.0438
1 1/4	12	1.2500	1.1959	0.0040	1.1999	1.1598	0.0090	1.1688
1 1/2	12	1.5000	1.4459	0.0040	1.4499	1.4098	0.0090	1.4188

[1] Basic diameter.

[2] Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\frac{1}{24} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

TABLE 19.—FINE-THREAD SERIES—CLOSE FIT (CLASS 4)—SCREWS

1	2	3	4	5	6	7	8	9
Size	Threads per Inch	Major Diameter in Inches			Pitch Diameter in Inches			Maximum[2] Minor Diameter in Inches
		Maximum[1]	Tolerance	Minimum	Maximum	Tolerance[3]	Minimum	
0	80	0.0600	0.0034	0.0566	0.0520	0.0006	0.0514	0.0447
1	72	0.0730	0.0036	0.0694	0.0641	0.0007	0.0634	0.0560
2	64	0.0860	0.0038	0.0822	0.0760	0.0007	0.0753	0.0668
3	56	0.0990	0.0040	0.0950	0.0876	0.0007	0.0869	0.0771
4	48	0.1120	0.0044	0.1076	0.0987	0.0008	0.0979	0.0864
5	44	0.1250	0.0046	0.1204	0.1104	0.0009	0.1096	0.0971
6	40	0.1380	0.0048	0.1332	0.1220	0.0009	0.1211	0.1073
8	36	0.1640	0.0050	0.1590	0.1462	0.0009	0.1453	0.1299
10	32	0.1900	0.0054	0.1846	0.1699	0.0010	0.1689	0.1517
12	28	0.2160	0.0062	0.2098	0.1930	0.0011	0.1919	0.1722
1/4	28	0.2500	0.0062	0.2438	0.2270	0.0011	0.2259	0.2062
5/16	24	0.3125	0.0066	0.3059	0.2857	0.0012	0.2845	0.2614
3/8	24	0.3750	0.0066	0.3684	0.3482	0.0012	0.3470	0.3239
7/16	20	0.4375	0.0072	0.4303	0.4053	0.0013	0.4040	0.3762
1/2	20	0.5000	0.0072	0.4928	0.4678	0.0013	0.4665	0.4387
9/16	18	0.5625	0.0082	0.5543	0.5267	0.0015	0.5252	0.4943
5/8	18	0.6250	0.0082	0.6168	0.5892	0.0015	0.5877	0.5568
3/4	16	0.7500	0.0090	0.7410	0.7098	0.0016	0.7082	0.6733
7/8	14	0.8750	0.0098	0.8652	0.8290	0.0018	0.8272	0.7874
1	14	1.0000	0.0098	0.9902	0.9540	0.0018	0.9522	0.9214
1 1/8	12	1.1250	0.0112	1.1138	1.0714	0.0020	1.0694	1.0228
1 1/4	12	1.2500	0.0112	1.2388	1.1964	0.0020	1.1944	1.1478
1 1/2	12	1.5000	0.0112	1.4888	1.4464	0.0020	1.4444	1.3978

[1] Basic diameter.

[2] Dimensions given are figured to the intersection of the worn-tool arc with a center line through crest and root. Minimum flat at root equals $\frac{1}{8} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

ABLE 20.—FINE-THREAD SERIES—CLOSE FIT (CLASS 4)—NUTS

1	2	3	6	7	8	9	10	11
Size	Threads per Inch	Minimum[1] Major Diameter[2] in Inches	Pitch Diameter in Inches			Minor Diameter in Inches		
			Minimum[1]	Tolerance[3]	Maximum	Minimum	Tolerance	Maximum
1/4	28	0.2500	0.2268	0.0011	0.2279	0.2113	0.0039	0.2152
5/16	24	0.3125	0.2854	0.0012	0.2866	0.2674	0.0045	0.2719
3/8	24	0.3750	0.3479	0.0012	0.3491	0.3299	0.0045	0.3344
7/16	20	0.4375	0.4050	0.0013	0.4063	0.3834	0.0054	0.3888
1/2	20	0.5000	0.4675	0.0013	0.4688	0.4459	0.0054	0.4513
9/16	18	0.5625	0.5264	0.0015	0.5279	0.5024	0.0060	0.5084
5/8	18	0.6250	0.5889	0.0015	0.5904	0.5649	0.0060	0.5709
3/4	16	0.7500	0.7094	0.0016	0.7110	0.6823	0.0068	0.6891
7/8	14	0.8750	0.8286	0.0018	0.8304	0.7977	0.0077	0.8054
1	14	1.0000	0.9536	0.0018	0.9554	0.9227	0.0077	0.9304
1 1/8	12	1.1250	1.0709	0.0020	1.0729	1.0348	0.0090	1.0438
1 1/4	12	1.2500	1.1959	0.0020	1.1979	1.1598	0.0090	1.1688
1 1/2	12	1.5000	1.4459	0.0020	1.4479	1.4098	0.0090	1.4188

[1] Basic diameter.

[2] Dimensions given are allowable only with tap having theoretically sharp orners. Threaded hole must not reject correct basic "go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

TABLE 21.—COARSE-THREAD SERIES—LOOSE FIT (CLASS 1)—NUTS

1	2	3	6	7	8	9	10	11
Size	Threads per Inch	Minimum[2] Major Diameter[3] in Inches	Pitch Diameter in Inches			Minor Diameter in Inches		
			Minimum[2]	Tolerance[4]	Maximum	Minimum	Tolerance	Maximum
1	64	0.0730	0.0629	0.0026	0.0655	0.0561	0.0017	0.057
2	56	0.0860	0.0744	0.0028	0.0772	0.0667	0.0019	0.068
3	48	0.0990	0.0855	0.0031	0.0886	0.0764	0.0023	0.078
4	40	0.1120	0.0958	0.0034	0.0992	0.0849	0.0027	0.087
5	40	0.1250	0.1088	0.0034	0.1122	0.0979	0.0027	0.100
6	32	0.1380	0.1177	0.0038	0.1215	0.1042	0.0034	0.107
8	32	0.1640	0.1437	0.0038	0.1475	0.1302	0.0034	0.133
10	24	0.1900	0.1629	0.0046	0.1675	0.1449	0.0045	0.149
12	24	0.2160	0.1889	0.0046	0.1935	0.1709	0.0045	0.175

[1] This fit is recommended for nuts only, in the numbered sizes.
[2] Basic diameter.
[3] Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\frac{1}{8} \times p$.
[4] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

Derivation of Tolerances

Net Pitch-Diameter Tolerance.—The net pitch diameter tolerances for the several classes or grades are based on selections from a tolerance series for a pitch of $\frac{1}{20}$ inch, increasing by increments of 0.00005 inch as follows:

GRADE	TOLERANCE	GRADE	TOLERANCE
A	0.0005 in.	F	0.0030 in.
B	0.0010 in.	G	0.0035 in.
C	0.0015 in.	H	0.0040 in.
D	0.0020 in.	I	0.0045 in.
E	0.0025 in.	J	0.0050 in.

The grades selected are:

For loose fit	I
For free fit	F
For medium fit	D
For close fit	B

Pitch-diameter tolerances for pitches finer than $\frac{1}{20}$ inch are to each other and to the tolerance for $\frac{1}{20}$ inch as the 0.6th power of their respective pitches.

Pitch-diameter tolerances for pitches coarser than $\frac{1}{20}$ inch are to each other and to the tolerance for $\frac{1}{20}$ inch as the 0.9th power of their respective pitches.

The factor 0.6 was chosen for pitches finer than $\frac{1}{20}$ inch because resulting tolerances except in two instances do not vary more than 0.0001 inch from the pitch-diameter tolerance in the A.S.M.E. Machine Screw Standard.

Extreme Pitch-Diameter Tolerance.—To obtain the extreme pitch diameter tolerance there is added to the net tolerance a "gage increment" obtained as follows:

To secure extreme tolerances, add to net tolerances:

Diameter tolerance—"go" gage
Diametrical equivalent of lead tolerance—"go" gage
Diametrical equivalent of angle tolerance—"go" gage
Diameter tolerance—"not go" gage

then subtract the following:

Diametrical equivalent of angle tolerance—"not go" gage,
$\frac{1}{2}$ diametrical equivalent of lead tolerance—"not go" gage.

For instance, using the tolerances (as set by the National Screw Thread Commission) for a 20-pitch gage, according to this rule the net tolerance would be increased by:

	Inches
Diameter tolerance—"go"	0.0002
Equivalent lead tolerance—"go"	0.00034
Equivalent angle tolerance—"go"	0.0002
Diameter tolerance—"not go"	0.0002
Total	0.00094

and would be decreased by:

Equivalent angle tolerance—"not go"	0.0002
$\frac{1}{2}$ lead tolerance—"not go"	0.00017
Total	0.00037

Total increase, 0.00094 − 0.00037 = 0.00057 inches.

Since the resulting extreme tolerances determine the actual allowable limits of the work itself, these only are given in the preceding tables. The actual net tolerances obtained will depend on the method of gaging used.

Relation of Lead and Angle Errors to Pitch-Diameter Tolerances

Effect of Lead Error on Pitch-Diameter Tolerance.—The tolerances specified for pitch diameters include all errors of pitch and angle. Column 4 of Tables 2, 3, 4 and 5 gives the amount of lead error which aborbs one-half of the specified pitch-diameter tolerance. Lead error × 1.732 = equivalent pitch-diameter error.

Effect of Angle Error on Pitch-Diameter Tolerance.—Column 5 of the above-mentioned tables gives the variation in the half

angle of thread which absorbs one-half of the specified pitch-diameter tolerance.

The formula giving the relation between the amount of pitch-diameter tolerance E' absorbed by a variation of a' in half angle of thread is, for symmetrical threads.

$$\cot a' = \frac{h}{E' \sin a \cos a} \pm \cot a$$

where h = depth of thread.
a = half angle of thread.
a' = error in half angle.

The sign of cot a is plus when the half-angle of thread is less than the basic by a' and minus when the half angle is greater than basic. The approximate mean values for a' and E' will be obtained when plus or minus cot a is omitted from the above formula. For American (National) form of screw thread the depth of thread.

$$h = \tfrac{3}{8}p \text{ cot } 30 \text{ deg. and } a = 30 \text{ degrees.}$$

Substituting, the formula becomes

$$\cot\ a' = \frac{3p}{2E'}$$

or

$$E' = \frac{3p}{2} \times \tan\ a' = 1.5\ p \tan a'$$

For all practical purposes, the equivalent pitch-diameter corrections for any angular error can be taken as proportional to the values given in the above tables. For example, on the $\frac{5}{16}$–18 thread, an angular error 1 degree 25 minutes is equivalent to a pitch-diameter error of 0.00206 inch. An angular error of 17 minutes or one-fifth the amount given in the table is equivalent to 0.00041 inch, which is almost directly proportional.

Tolerances for Loose Fit (Class 1)

This fit is recommended whenever an *allowance* is required between the maximum screw and the minimum nut, and in the cases where larger tolerances than those given by the free fit (Class 2) are needed.

This class of screw threads will be defined and specified as follows:

Minimum Nut is Basic.

Maximum Screw is below Basic.

The major diameter and pitch diameter of the maximum screw will be below basic in accordance with the diameter specified in Tables 22 and 24.

Direction of Tolerance on the Nut: The tolerance on the nut will be plus.

Direction of Tolerance on the Screw: The tolerance on the screw will be minus.

Tolerance Values: The tolerances on a screw or nut of given diameter and pitch will be such as to result from the dimensions given in Tables 22, 23, 24 and 25.

TABLE 22.—COARSE-THREAD SERIES—LOOSE FIT (CLASS 1)—SCREWS

1	2	3	4	5	6	7	8
Size	Threads per Inch	Major Diameter in Inches			Pitch Diameter[1] in Inches		Maximum Minor Diameter[2] in Inches
		Maximum	Tolerance	Minimum	Maximum	Minimum	
1	64	0.0723	0.0052	0.0671	0.0622	0.0596	0.0531
2	56	0.0852	0.0056	0.0796	0.0736	0.0708	0.0633
3	48	0.0981	0.0062	0.0919	0.0846	0.0815	0.0725
4	40	0.1110	0.0068	0.1042	0.0948	0.0914	0.0803
5	40	0.1240	0.0068	0.1172	0.1078	0.1044	0.0933
6	32	0.1369	0.0076	0.1293	0.1166	0.1128	0.0986
8	32	0.1629	0.0076	0.1553	0.1426	0.1388	0.1246
10	24	0.1887	0.0092	0.1795	0.1616	0.1570	0.1376
12	24	0.2147	0.0092	0.2055	0.1876	0.1830	0.1636
1/4	20	0.2485	0.0102	0.2383	0.2160	0.2109	0.1872
5/16	18	0.3109	0.0114	0.2995	0.2748	0.2691	0.2427
3/8	16	0.3732	0.0126	0.3606	0.3326	0.3263	0.2965
7/16	14	0.4354	0.0140	0.4214	0.3890	0.3820	0.3478
1/2	13	0.4978	0.0148	0.4830	0.4478	0.4404	0.4034
9/16	12	0.5601	0.0158	0.5443	0.5060	0.4981	0.4579
5/8	11	0.6224	0.0170	0.6054	0.5634	0.5549	0.5109
3/4	10	0.7472	0.0184	0.7288	0.6822	0.6730	0.6245
7/8	9	0.8719	0.0200	0.8519	0.7997	0.7897	0.7356
1	8	0.9966	0.0222	0.9744	0.9154	0.9043	0.8432
1 1/8	7	1.1211	0.0248	1.0963	1.0283	1.0159	0.9458
1 1/4	7	1.2461	0.0248	1.2213	1.1533	1.1409	1.0708
1 3/8	6	1.4956	0.0290	1.4666	1.3873	1.3728	1.2911
1 1/2	5	1.7448	0.0338	1.7110	1.6149	1.5980	1.4994
2	4 1/2	1.9943	0.0368	1.9575	1.8500	1.8316	1.7217
2 1/4	4 1/2	2.2443	0.0368	2.2075	2.1000	2.0816	1.9717
2 1/2	4	2.4936	0.0408	2.4528	2.3312	2.3108	2.1869
2 3/4	4	2.7436	0.0408	2.7028	2.5812	2.5608	2.4369
3	4	2.9936	0.0408	2.9528	2.8312	2.8108	2.6869

[1] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

[2] Dimensions given are figured to the intersection of the worn-tool arc with a center line through crest and root. Minimum flat at root equal $\frac{1}{8} \times p$.

TABLE 23.—COARSE-THREAD SERIES, LOOSE FIT (CLASS 1)—NUTS

1	2	3	4	5	6	7
Size	Threads per Inch	Minimum Major[1] Diameter[2] in Inches	Pitch Diameter[3] in Inches		Minor Diameter in Inches	
			Minimum	Maximum	Minimum	Maximum
1	64	0.0730	0.0629	0.0655	0.0561	0.0578
2	56	0.0860	0.0744	0.0772	0.0667	0.0686
3	48	0.0990	0.0855	0.0886	0.0764	0.0787
4	40	0.1120	0.0958	0.0992	0.0849	0.0876
5	40	0.1250	0.1088	0.1122	0.0979	0.1006
6	32	0.1380	0.1177	0.1215	0.1042	0.1076
8	32	0.1640	0.1437	0.1475	0.1302	0.1336
10	24	0.1900	0.1629	0.1675	0.1449	0.1494
12	24	0.2160	0.1889	0.1935	0.1709	0.1754
1/4	20	0.2500	0.2175	0.2226	0.1959	0.2013
5/16	18	0.3125	0.2764	0.2821	0.2524	0.2584
3/8	16	0.3750	0.3344	0.3407	0.3073	0.3141
7/16	14	0.4375	0.3911	0.3981	0.3602	0.3679
1/2	13	0.5000	0.4500	0.4574	0.4167	0.4251
9/16	12	0.5625	0.5084	0.5163	0.4723	0.4813
5/8	11	0.6250	0.5660	0.5745	0.5266	0.5364
3/4	10	0.7500	0.6850	0.6942	0.6417	0.6526
7/8	9	0.8750	0.8028	0.8128	0.7547	0.7667
1	8	1.0000	0.9188	0.9299	0.8647	0.8782
1 1/8	7	1.1250	1.0322	1.0446	0.9704	0.9858
1 1/4	7	1.250	1.1572	1.1696	1.0954	1.1108
1 1/2	6	1.500	1.3917	1.4062	1.3196	1.3376
1 3/4	5	1.750	1.6201	1.6370	1.5335	1.5551
	4 1/2	2.000	1.8557	1.8741	1.7594	1.7835
2 1/4	4 1/2	2.250	2.1057	2.1241	2.0094	2.0335
2 1/2	4	2.500	2.3376	2.3580	2.2294	2.2564
2 3/4	4	2.750	2.5876	2.6080	2.4794	2.5064
3	4	3.000	2.8376	2.8580	2.7294	2.7564

[1] Basic diameter.

[2] Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "go" gag by interference with rounded roots due to worn tap. Minimum flat at roo equals $\frac{p}{4} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and als include errors of lead and angle.

NOTE: For numbered sizes of nuts see also Table 7, page 48.

TABLE 24.—FINE-THREAD SERIES—LOOSE FIT (CLASS 1)—SCREWS

1	2	3	4	5	6	7
Size	Threads per Inch	Major Diameter in Inches		Pitch Diameter[1] in Inches		Maximum Minor[2] Diameter in Inches
		Maximum	Minimum	Maximum	Minimum	
0	80	0.0593	0.0545	0.0512	0.0488	0.0440
1	72	0.0723	0.0673	0.0633	0.0608	0.0553
2	64	0.0853	0.0801	0.0752	0.0726	0.0661
3	56	0.0982	0.0926	0.0866	0.0838	0.0763
4	48	0.1111	0.1049	0.0976	0.0945	0.0855
5	44	0.1241	0.1117	0.1093	0.1061	0.0962
6	40	0.1370	0.1302	0.1208	0.1174	0.1063
8	36	0.1629	0.1557	0.1449	0.1413	0.1288
10	32	0.1889	0.1813	0.1686	0.1648	0.1506
12	28	0.2148	0.2062	0.1916	0.1873	0.1710
1/4	28	0.2488	0.2402	0.2256	0.2213	0.2050
5/16	24	0.3112	0.3020	0.2841	0.2795	0.2601
3/8	24	0.3737	0.3645	0.3466	0.3420	0.3226
7/16	20	0.4360	0.4258	0.4035	0.3984	0.3747
1/2	20	0.4985	0.4883	0.4660	0.4609	0.4372
9/16	18	0.5609	0.5495	0.5248	0.5191	0.4927
5/8	18	0.6234	0.6120	0.5873	0.5816	0.5552
3/4	16	0.7482	0.7356	0.7076	0.7013	0.6715
7/8	14	0.8729	0.8589	0.8265	0.8195	0.7853
1	14	0.9979	0.9839	0.9515	0.9445	0.9103
1 1/8	12	1.1226	1.1068	1.0685	1.0606	1.0204
1 1/4	12	1.2476	1.2318	1.1935	1.1856	1.1454
1 1/2	12	1.4976	1.4818	1.4435	1.4356	1.3954

[1] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

[2] Dimensions given are figured to the intersection of the worn-tool arc with a center line through crest and root. Minimum flat at root equals $\frac{1}{8} \times p$.

TABLE 25.—FINE-THREAD SERIES—LOOSE FIT (CLASS 1)—NUTS

1	2	3	4	5	6	7
Size	Threads per Inch	Minimum Major[1] Diameter[2] in Inches	Pitch Diameter[3] in Inches		Minor Diameter in Inches	
			Minimum	Maximum	Minimum	Maximum
0	80	0.0600	0.0519	0.0543	0.0465	0.0478
1	72	0.0730	0.0640	0.0665	0.0580	0.0595
2	64	0.0860	0.0759	0.0785	0.0691	0.0708
3	56	0.0990	0.0874	0.0902	0.0797	0.0816
4	48	0.1120	0.0985	0.1016	0.0894	0.0917
5	44	0.1250	0.1102	0.1134	0.1004	0.1029
6	40	0.1380	0.1218	0.1252	0.1109	0.1136
8	36	0.1640	0.1460	0.1496	0.1339	0.1369
10	32	0.1900	0.1697	0.1735	0.1562	0.1596
12	28	0.2160	0.1928	0.1971	0.1773	0.1812
1/4	28	0.2500	0.2268	0.2311	0.2113	0.2152
5/16	24	0.3125	0.2854	0.2900	0.2674	0.2719
3/8	24	0.3750	0.3479	0.3525	0.3299	0.3344
7/16	20	0.4375	0.4050	0.4101	0.3834	0.3888
1/2	20	0.5000	0.4675	0.4726	0.4459	0.4513
9/16	18	0.5625	0.5264	0.5321	0.5024	0.5084
5/8	18	0.6250	0.5889	0.5946	0.5649	0.5709
3/4	16	0.7500	0.7094	0.7157	0.6823	0.6891
7/8	14	0.8750	0.8286	0.8356	0.7977	0.8054
1	14	1.0000	0.9536	0.9606	0.9227	0.9304
1 1/8	12	1.1250	1.0709	1.0788	1.0348	1.0438
1 1/4	12	1.2500	1.1959	1.2038	1.1598	1.1688
1 1/2	12	1.5000	1.4459	1.4538	1.4098	1.4188

[1] Basic diameter.

[2] Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\frac{1}{24} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and also include errors of lead and angle.

NOTE: For numbered sizes of nuts see also Table 15, page 56.

The S.A.E. adopted an extra fine-thread series in 1915, for use in aeronautic and other work requiring a fine thread. No tolerances have yet been determined for these. The threads are: 1/4 inch = 36, 5/16 − 3/8 = 32, 7/16 − 1/2 = 28, 9/16 − 5/8 = 24, 3/4 − 7/8 − 1 = 20, 1 1/8 − 1 1/4 − 1 1/2 = 18, and all larger diameters = 16 threads per inch.

EXTRA-FINE THREAD FITS—AMERICAN THREAD

For such purposes as small pipe fittings, tank and radiator caps, etc. the S. A. E. recommend an extra-fine thread, the basic dimensions being given in Table 26. For different classes of fits in this thread, Earle Buckingham has worked out the tolerances shown in Tables 21 to 32. Notations under Table 28 also apply to Tables 30 and 31. Notations under Table 2 also apply to Tables 29 and 32.

TABLE 26.—BASIC DIAMETERS AND THREAD DATA FOR THE EXTRA-FINE THREAD SERIES

(Dimensions in Inches)

Sizes	Threads per Inch	Basic Major Diameter	Basic Pitch Diameter	Basic Minor Diameter	Pitch[1]	Basic Depth of Thread
10	40	0.1900	0.1738	0.1575	0.0250000	0.01624
1/4	36	0.2500	0.2320	0.2139	0.0277778	0.01804
5/16	32	0.3125	0.2922	0.2719	0.0312500	0.02030
3/8	32	0.3750	0.3547	0.3344	0.0312500	0.02030
7/16	28	0.4375	0.4143	0.3911	0.0357143	0.02319
1/2	28	0.5000	0.4768	0.4536	0.0357143	0.02319
9/16	24	0.5625	0.5354	0.5084	0.0416667	0.02706
5/8	24	0.6250	0.5979	0.5709	0.0416667	0.02706
3/4	20	0.7500	0.7175	0.6850	0.0500000	0.03248
7/8	20	0.8750	0.8425	0.8100	0.0500000	0.03248
1	20	1.0000	0.9675	0.9350	0.0500000	0.03248
1 1/8	18	1.1250	1.0889	1.0528	0.0555556	0.03608
1 1/4	18	1.2500	1.2139	1.1778	0.0555556	0.03608
1 3/8	18	1.3750	1.3389	1.3028	0.0555556	0.03608
1 1/2	18	1.5000	1.4639	1.4278	0.0555556	0.03608
1 3/4	16	1.7500	1.7094	1.6778	0.0625000	0.04060
2	16	2.0000	1.9594	1.9278	0.0625000	0.04060
2 1/4	16	2.2500	2.2094	2.1778	0.0625000	0.04060
2 1/2	16	2.5000	2.4594	2.4278	0.0625000	0.04060
2 3/4	16	2.7500	2.7094	2.6778	0.0625000	0.04060
3	16	3.0000	2.9594	2.9278	0.0625000	0.04060
3 1/2	16	3.5000	3.4594	3.4278	0.0625000	0.04060
4	16	4.0000	3.9594	3.9278	0.0625000	0.04060

[1] This column is given to seven decimal places for computation purposes only.

TABLE 27.—LOOSE FIT (CLASS B) FOR SCREWS IN THE EXTRA-FINE THREAD SERIES[1]

(Dimensions in Inches)

Size	Threads per Inch	Major Diameter			Pitch Diameter			Maximum[4] Minor Diameter
		Maximum[2]	Tolerance	Minimum	Maximum[2]	Tolerance[3]	Minimum	
10	40	0.1900	0.0068	0.1832	0.1738	0.0043	0.1695	0.1593
1/4	36	0.2500	0.0072	0.2428	0.2320	0.0046	0.2274	0.2159
5/16	32	0.3125	0.0076	0.3049	0.2922	0.0050	0.2872	0.2742
3/8	32	0.3750	0.0076	0.3674	0.3547	0.0051	0.3496	0.3367
7/16	28	0.4375	0.0086	0.4289	0.4143	0.0055	0.4088	0.3937
1/2	28	0.5000	0.0086	0.4914	0.4768	0.0056	0.4712	0.4562
9/16	24	0.5625	0.0092	0.5533	0.5354	0.0060	0.5294	0.5114
5/8	24	0.6250	0.0092	0.6158	0.5979	0.0061	0.5918	0.5739
3/4	20	0.7500	0.0102	0.7398	0.7175	0.0067	0.7108	0.6887
7/8	20	0.8750	0.0102	0.8648	0.8425	0.0068	0.8357	0.8137
1	20	1.0000	0.0102	0.9898	0.9675	0.0070	0.9605	0.9387
1 1/8	18	1.1250	0.0114	1.1136	1.0880	0.0074	1.0815	1.0568
1 1/4	18	1.2500	0.0114	1.2386	1.2130	0.0075	1.2064	1.1818
1 3/8	18	1.5000	0.0114	1.4886	1.4639	0.0077	1.4562	1.4318
1 1/2	16	1.7500	0.0126	1.7374	1.7094	0.0083	1.7011	1.6733
2	16	2.0000	0.0126	1.9874	1.9594	0.0085	1.9509	1.9233
2 1/4	16	2.2500	0.0126	2.2374	2.2094	0.0086	2.2008	2.1733
2 1/2	16	2.5000	0.0126	2.4874	2.4594	0.0088	2.4506	2.4233
2 3/4	16	2.7500	0.0126	2.7374	2.7094	0.0089	2.7005	2.6733
3	16	3.0000	0.0126	2.9874	2.9594	0.0091	2.9503	2.9233
3 1/4	16	3.5000	0.0126	3.4874	3.4594	0.0094	3.4500	3.4233
4	16	4.0000	0.0126	3.9874	3.9594	0.0096	3.9498	3.9233

[1] Based on 1924 Report of the National Screw Thread Commission, using a standard length of engagement of five threads.

[2] Basic diameter.

[3] The tolerances specified for pitch diameter are cumulative and include errors of lead and angle.

[4] Dimensions given are figured to the intersection of the worn-tool arc with a center line through crest and root. Minimum flat at root equals $\frac{1}{8} \times p$.

TABLE 28.—LOOSE FIT (CLASS B) FOR NUTS IN THE EXTRA-FINE THREAD SERIES[1]

(Dimensions in Inches)

Size	Threads per Inch	Minimum Major Diameter[2]	Pitch Diameter			Minor Diameter		
			Minimum[3]	Tolerance[4]	Maximum	Minimum	Tolerance	Maximum
10	40	0.1900	0.1738	0.0043	0.1781	0.1629	0.0027	0.1656
1/4	36	0.2500	0.2320	0.0046	0.2366	0.2190	0.0030	0.2229
5/16	32	0.3125	0.2922	0.0050	0.2972	0.2787	0.0034	0.2821
3/8	32	0.3750	0.3547	0.0051	0.3598	0.3412	0.0034	0.3446
7/16	28	0.4375	0.4143	0.0055	0.4198	0.3988	0.0039	0.4027
1/2	28	0.5000	0.4768	0.0056	0.4824	0.4613	0.0039	0.4652
9/16	24	0.5625	0.5354	0.0060	0.5414	0.5174	0.0045	0.5219
5/8	24	0.6250	0.5979	0.0061	0.6040	0.5799	0.0045	0.5844
3/4	20	0.7500	0.7175	0.0067	0.7242	0.6959	0.0054	0.7013
7/8	20	0.8750	0.8425	0.0068	0.8493	0.8209	0.0054	0.8263
1	20	1.0000	0.9675	0.0070	0.9745	0.9459	0.0054	0.9513
1 1/8	18	1.1250	1.0889	0.0074	1.0963	1.0649	0.0060	1.0709
1 1/4	18	1.2500	1.2139	0.0075	1.2214	1.1899	0.0060	1.1959
1 3/8	18	1.5000	1.4639	0.0077	1.4716	1.4399	0.0060	1.4459
1 3/4	16	1.7500	1.7094	0.0083	1.7177	1.6823	0.0068	1.6891
2	16	2.0000	1.9594	0.0085	1.9679	1.9323	0.0068	1.9391
2 1/4	16	2.2500	2.2094	0.0086	2.2180	2.1823	0.0068	2.1891
2 1/2	16	2.5000	2.4594	0.0088	2.4682	2.4323	0.0068	2.4391
2 3/4	16	2.7500	2.7094	0.0089	2.7183	2.6823	0.0068	2.6891
3	16	3.0000	2.9594	0.0091	2.9685	2.9323	0.0068	2.9391
3 1/4	16	3.5000	3.4594	0.0094	3.4688	3.4323	0.0068	3.4391
4	16	4.0000	3.9594	0.0096	3.9690	3.9323	0.0068	3.9391

[1] Based on 1924 Report of the National Screw Thread Commission using a standard length of engagement of five threads.

[2] Basic diameter. Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\frac{1}{24} \times p$.

[3] Basic diameter.

[4] The tolerances specified for pitch diameter are cumulative and include errors of lead and angle.

TABLE 29.—FREE FIT (CLASS C) FOR SCREWS IN THE EXTRA-FINE THREAD SERIES
(Dimensions in Inches)

Size	Threads per Inch	Major Diameter			Pitch Diameter			Maximum Minor Diameter
		Maximum	Tolerance	Minimum	Maximum	Tolerance	Minimum	
10	40	0.1900	0.0048	0.1852	0.1738	0.0027	0.1711	0.1593
1/4	36	0.2500	0.0050	0.2450	0.2320	0.0030	0.2290	0.2159
5/16	32	0.3125	0.0054	0.3071	0.2922	0.0032	0.2890	0.2742
5/16	32	0.3750	0.0054	0.3696	0.3547	0.0033	0.3514	0.3367
7/16	28	0.4375	0.0062	0.4313	0.4143	0.0036	0.4107	0.3937
1/2	28	0.5000	0.0062	0.4938	0.4768	0.0037	0.4731	0.4562
9/16	24	0.5625	0.0066	0.5559	0.5354	0.0040	0.5314	0.5114
9/16	24	0.6250	0.0066	0.6184	0.5979	0.0041	0.5938	0.5739
5/8	20	0.7500	0.0072	0.7428	0.7175	0.0045	0.7130	0.6887
5/8	20	0.8750	0.0072	0.8678	0.8425	0.0046	0.8359	0.8137
1	20	1.0000	0.0072	0.9928	0.9675	0.0047	0.9628	0.9387
1 1/8	18	1.1250	0.0082	1.1168	1.0889	0.0050	1.0839	1.0568
1 1/4	18	1.2500	0.0082	1.2418	1.2139	0.0051	1.2088	1.1818
1 3/8	18	1.5000	0.0082	1.4918	1.4639	0.0054	1.4585	1.4318
1 3/4	16	1.7500	0.0090	1.7410	1.7094	0.0058	1.7036	1.6733
2	16	2.0000	0.0090	1.9910	1.9594	0.0060	1.9534	1.9233
2 1/4	16	2.2500	0.0090	2.2410	2.2094	0.0061	2.2033	2.1733
2 1/2	16	2.5000	0.0090	2.4910	2.4594	0.0063	2.4531	2.4233
2 3/4	16	2.7500	0.0090	2.7410	2.7094	0.0064	2.7030	2.6733
3	16	3.0000	0.0090	2.9910	2.9594	0.0066	2.9528	2.9233
3 1/2	16	3.5000	0.0090	3.4910	3.4594	0.0069	3.4525	3.4233
4	16	4.0000	0.0090	3.9910	3.9594	0.0071	3.9523	3.9233

TABLE 30.—FREE FIT (CLASS C) FOR NUTS IN THE EXTRA-FINE THREAD SERIES

(Dimensions in Inches)

Size	Threads per Inch	Minimum Major Diameter	Pitch Diameter			Minor Diameter		
			Minimum	Tolerance	Maximum	Minimum	Tolerance	Maximum
10	40	0.1900	0.1738	0.0027	0.1765	0.1629	0.0027	0.1656
1/4	36	0.2500	0.2320	0.0030	0.2350	0.2199	0.0030	0.2229
5/16	32	0.3125	0.2922	0.0032	0.2954	0.2787	0.0034	0.2821
3/8	32	0.3750	0.3547	0.0033	0.3580	0.3412	0.0034	0.3446
7/16	28	0.4375	0.4143	0.0036	0.4179	0.3988	0.0039	0.4027
1/2	28	0.5000	0.4768	0.0037	0.4805	0.4613	0.0039	0.4652
9/16	24	0.5625	0.5354	0.0040	0.5394	0.5174	0.0045	0.5219
5/8	24	0.6250	0.5979	0.0041	0.6020	0.5799	0.0045	0.5844
3/4	20	0.7500	0.7175	0.0045	0.7220	0.6959	0.0054	0.7013
7/8	20	0.8750	0.8425	0.0046	0.8471	0.8209	0.0054	0.8263
1	20	1.0000	0.9675	0.0047	0.9722	0.9459	0.0054	0.9513
1 1/8	18	1.1250	1.0889	0.0050	1.0939	1.0649	0.0060	1.0709
1 1/4	18	1.2500	1.2139	0.0051	1.2190	1.1899	0.0060	1.1959
1 3/8	18	1.5000	1.4639	0.0054	1.4693	1.4399	0.0060	1.4459
1 1/2	16	1.7500	1.7094	0.0058	1.7152	1.6823	0.0068	1.6891
2	16	2.0000	1.9594	0.0060	1.9654	1.9323	0.0068	1.9391
2 1/4	16	2.2500	2.2094	0.0061	2.2155	2.1823	0.0068	2.1891
2 1/2	16	2.5000	2.4594	0.0063	2.4657	2.4323	0.0068	2.4391
2 3/4	16	2.7500	2.7094	0.0064	2.7158	2.6823	0.0068	2.6891
3	16	3.0000	2.9594	0.0066	2.9660	2.9323	0.0068	2.9391
3 1/2	16	3.5000	3.4594	0.0069	3.4663	3.4323	0.0068	3.4391
4	16	4.0000	3.9594	0.0071	3.9665	3.9323	0.0068	3.9391

TABLE 31.—MEDIUM FIT (CLASS D) FOR SCREWS IN THE EXTRA-FINE THREAD SERIES
(Dimensions in Inches)

Size	Threads per Inch	Major Diameter			Pitch Diameter			Maximum Minor Diameter
		Maximum	Tolerance	Minimum	Maximum	Tolerance	Minimum	
10	40	0.1900	0.0048	0.1852	0.1738	0.0019	0.1719	0.1593
1/4	36	0.2500	0.0050	0.2450	0.2320	0.0021	0.2299	0.2159
5/16	32	0.3125	0.0054	0.3071	0.2922	0.0023	0.2899	0.2742
3/8	32	0.3750	0.0054	0.3696	0.3547	0.0024	0.3523	0.3367
7/16	28	0.4375	0.0062	0.4313	0.4143	0.0026	0.4117	0.3937
1/2	28	0.5000	0.0062	0.4938	0.4768	0.0027	0.4741	0.4562
9/16	24	0.5625	0.0066	0.5559	0.5354	0.0029	0.5325	0.5118
5/8	24	0.6250	0.0066	0.6184	0.5979	0.0030	0.5949	0.5736
11/16	20	0.7500	0.0072	0.7428	0.7175	0.0034	0.7141	0.6887
3/4	20	0.8750	0.0072	0.8678	0.8425	0.0035	0.8390	0.8137
1	20	1.0000	0.0072	0.9928	0.9675	0.0036	0.9639	0.9387
1 1/8	18	1.1250	0.0082	1.1168	1.0880	0.0039	1.0850	1.0562
1 1/4	18	1.2500	0.0082	1.2418	1.2130	0.0040	1.2099	1.1812
1 3/8	18	1.5000	0.0082	1.4918	1.4630	0.0042	1.4597	1.4312
1 3/4	16	1.7500	0.0090	1.7410	1.7094	0.0045	1.7049	1.6737
2	16	2.0000	0.0090	1.9910	1.9594	0.0047	1.9547	1.9237
2 1/4	16	2.2500	0.0090	2.2410	2.2094	0.0049	2.2045	2.1737
2 1/2	16	2.5000	0.0090	2.4910	2.4594	0.0050	2.4544	2.4237
2 3/4	16	2.7500	0.0090	2.7410	2.7094	0.0052	2.7042	2.6737
3	16	3.0000	0.0090	2.9910	2.9594	0.0053	2.9541	2.9237
3 1/2	16	3.5000	0.0090	3.4910	3.4594	0.0056	3.4538	3.4237
4	16	4.0000	0.0090	3.9910	3.9594	0.0059	3.9535	3.9237

TABLE 32.—MEDIUM FIT (CLASS D) FOR NUTS IN THE EXTRA-FINE THREAD SERIES
(Dimensions in Inches)

Size	Threads per Inch	Minimum Major Diameter	Pitch Diameter			Minor Diameter		
			Minimum	Tolerance	Maximum	Minimum	Tolerance	Maximum
10	40	0.1900	0.1738	0.0019	0.1757	0.1629	0.0027	0.1656
1/4	36	0.2500	0.2320	0.0021	0.2341	0.2199	0.0030	0.2229
5/16	32	0.3125	0.2922	0.0023	0.2945	0.2787	0.0034	0.2821
3/8	32	0.3750	0.3547	0.0024	0.3571	0.3412	0.0034	0.3446
7/16	28	0.4375	0.4143	0.0026	0.4169	0.3988	0.0039	0.4027
1/2	28	0.5000	0.4768	0.0027	0.4795	0.4613	0.0039	0.4652
9/16	24	0.5625	0.5354	0.0029	0.5383	0.5174	0.0045	0.5219
5/8	24	0.6250	0.5979	0.0030	0.6009	0.5799	0.0045	0.5844
3/4	20	0.7500	0.7175	0.0034	0.7209	0.6959	0.0054	0.7013
7/8	20	0.8750	0.8425	0.0035	0.8460	0.8209	0.0054	0.8263
1	20	1.0000	0.9675	0.0036	0.9711	0.9459	0.0054	0.9513
1 1/8	18	1.1250	1.0889	0.0039	1.0928	1.0649	0.0060	1.0709
1 1/4	18	1.2500	1.2139	0.0040	1.2179	1.1899	0.0060	1.1959
1 3/8	18	1.5000	1.4639	0.0042	1.4681	1.4399	0.0060	1.4459
1 1/4	16	1.7500	1.7094	0.0045	1.7139	1.6823	0.0068	1.6891
2	16	2.0000	1.9594	0.0047	1.9641	1.9323	0.0068	1.9391
2 1/4	16	2.2500	2.2094	0.0049	2.2143	2.1823	0.0068	1.1891
2 1/2	16	2.5000	2.4594	0.0050	2.4644	2.4323	0.0068	2.4391
2 3/4	16	2.7500	2.7094	0.0052	2.7146	2.6823	0.0068	2.6891
3	16	3.0000	2.9594	0.0053	2.9647	2.9323	0.0068	2.9391
3 1/2	16	3.5000	3.4594	0.0056	3.4650	3.4323	0.0068	3.4391
4	16	4.0000	3.9594	0.0059	3.9653	3.9323	0.0068	3.9391

BRITISH STANDARD WHITWORTH THREADS

The British Engineering Standards Association have adopted new standards for threads used in Great Britain, these standards, as in the United States, including pitch diameter, angle and lead and tolerances on them all. There are differences in terms, both as to threads and gages. The main differences are:

American Standard = British Standard
Major diameter = Full diameter
Minor diameter = Core diameter
Pitch diameter = Effective diameter

By bearing these differences in mind, the tables will be clear, as it seems best to give them exactly as adopted by the B. E. S. A. Very complete tables have been compiled to show the corrections to effective (pitch) diameter required to compensate for errors of both pitch and angle in the Whitworth form of thread, but no tolerances are given as to the exact shape or size of the radius, as these should always clear except in special cases. These tables are copyrighted and may be obtained from the B. E. S. A. in London by whose permission they are used here.

Tolerances are calculated as follows:

	Full Diameter	Effective Diameter	Core Diameter
Bolt	$3 \times 0.01\sqrt{p}$	$2 \times 0.01\sqrt{p}$	$4 \times 0.01\sqrt{p}$
Nut	$4 \times 0.01\sqrt{p}$	$2 \times 0.01\sqrt{p}$	$3 \times 0.01\sqrt{p}$

The term "grade" is used to express the sum of the errors on effective diameter and on pitch and angle measured as diametral errors. "Play" is used for the difference between the effective diameter error and the sum of the other two. The limits for grade and play are:

Grade $= 4 \times 0.1\sqrt{p}$. Play $= 2 \times 0.01\sqrt{p}$.

TABLE 33.—STANDARD DIMENSIONS OF BRITISH STANDARD WHITWORTH SCREW THREADS—55-DEGREE ANGLE

1	2	3	4	5	6	7	8	9	10	11	12
Nominal Diam. of Screw in Inches	No. of Threads per Inch	Pitch in Inches	Depth of Thread in Inches	Full Diameter, in Inches		Effective Diameter, in Inches		Core Diameter, in Inches		Cross Sectional Area at Bottom of Thread of Bolt in Square Inches	Nominal Diam. of Screw in Inches
				Bolt	Nut	Bolt	Nut	Bolt	Nut		
1/8	20	0.05000	0.03200	0.2500	0.2520	0.2180	0.2200	0.1860	0.1880	0.0272	1/8
5/32	18	0.05556	0.03555	0.3125	0.3145	0.2769	0.2789	0.2414	0.2434	0.0458	5/32
3/16	16	0.06250	0.04000	0.3750	0.3770	0.3350	0.3370	0.2950	0.2970	0.0683	3/16
7/32	14	0.07143	0.04575	0.4375	0.4395	0.3918	0.3938	0.3460	0.3480	0.0940	7/32
1/4	12	0.08333	0.05335	0.5000	0.5020	0.4466	0.4486	0.3933	0.3953	0.1215	1/4
9/32	12	0.08333	0.05335	0.5625	0.5645	0.5091	0.5111	0.4558	0.4578	0.1632	9/32
5/16	11	0.09091	0.05820	0.6250	0.6270	0.5668	0.5688	0.5086	0.5106	0.2032	5/16
11/32	10	0.10000	0.06405	0.7500	0.7520	0.6860	0.6880	0.6219	0.6239	0.3038	11/32
3/8	9	0.11111	0.07115	0.8750	0.8770	0.8039	0.8059	0.7327	0.7347	0.4216	3/8
1	8	0.12500	0.08005	1.0000	1.0020	0.9200	0.9220	0.8399	0.8419	0.5540	1
1 1/8	7	0.14286	0.09150	1.1250	1.1270	1.0335	1.0355	0.9420	0.9440	0.6969	1 1/8
1 1/4	7	0.14286	0.09150	1.2500	1.2520	1.1585	1.1605	1.0670	1.0690	0.8942	1 1/4
1 1/2	6	0.16667	0.10670	1.5000	1.5020	1.3933	1.3953	1.2866	1.2886	1.3001	1 1/2
1 3/4	5	0.20000	0.12805	1.7500	1.7520	1.6219	1.6239	1.4939	1.4959	1.7528	1 3/4
2	4.5	0.22222	0.14230	2.0000	2.0020	1.8577	1.8597	1.7154	1.7174	2.3111	2
2 1/4	4	0.25000	0.16010	2.2500	2.2520	2.0899	2.0919	1.9298	1.9318	2.9249	2 1/4
2 1/2	4	0.25000	0.16010	2.5000	2.5020	2.3399	2.3419	2.1798	2.1818	3.7318	2 1/2
2 3/4	3.5	0.28571	0.18295	2.7500	2.7520	2.5670	2.5690	2.3841	2.3861	4.4641	2 3/4
3	3.5	0.28571	0.18295	3.0000	3.0020	2.8170	2.8190	2.6341	2.6361	5.4496	3

The complete table list includes 1 1/16, 1 3/16, 1 5/16, 1 7/8, 1 15/16, 2 1/16, 2 3/16, 2 5/16 and 2 7/8 inches but the B. E. A. advises against their use.

TABLE 34.—BRITISH STANDARD WHITWORTH SCREW THREADS, STANDARD SIZES AND TOLERANCES—BOLTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Nominal Diam. of Screw in Inches	No. of Threads per Inch	Pitch in Inches	Tolerances See Note A		Full Diameter in Inches			Effective Diameter in Inches			Core Diameter in Inches			Grade	Maximum Play Permissible
			Pitch in Inches	Angle in Degrees	Max.	Tol.	Min.	Max.	Tol.	Min.	Max.	Tol.	Min.	Thousandths of an Inch	Thousandths of an Inch
1/4	20	0.05000	0.0012	4.3	0.2500	0.0067	0.2433	0.2180	0.0045	0.2135	0.1860	0.0090	0.1770	9.0	4.5
5/16	18	0.05556	0.0012	4.0	0.3125	0.0071	0.3054	0.2769	0.0047	0.2722	0.2414	0.0094	0.2320	9.4	4.7
3/8	16	0.06250	0.0013	3.8	0.3750	0.0075	0.3675	0.3350	0.0050	0.3300	0.2950	0.0100	0.2850	10.0	5.0
7/16	14	0.07143	0.0014	3.5	0.4375	0.0080	0.4295	0.3918	0.0053	0.3865	0.3460	0.0107	0.3353	10.6	5.3
1/2	12	0.08333	0.0015	3.3	0.5000	0.0087	0.4913	0.4466	0.0058	0.4408	0.3933	0.0115	0.3818	11.6	5.8
9/16	12	0.08333	0.0015	3.3	0.5625	0.0087	0.5538	0.5091	0.0058	0.5033	0.4558	0.0115	0.4443	11.6	5.8
5/8	11	0.09091	0.0016	3.2	0.6250	0.0090	0.6160	0.5668	0.0060	0.5608	0.5086	0.0121	0.4965	12.0	6.0
11/16	10	0.10000	0.0016	3.0	0.7500	0.0095	0.7405	0.6860	0.0063	0.6797	0.6219	0.0126	0.6093	12.6	6.3
3/4	9	0.11111	0.0017	2.9	0.8750	0.0100	0.8650	0.8039	0.0067	0.7972	0.7327	0.0133	0.7194	13.4	6.7
1	8	0.12500	0.0018	2.7	1.0000	0.0106	0.9894	0.9200	0.0071	0.9129	0.8399	0.0141	0.8258	14.2	7.1
1 1/8	7	0.14286	0.0020	2.5	1.1250	0.0113	1.1137	1.0335	0.0076	1.0259	0.9420	0.0151	0.9269	15.2	7.6
1 1/4	7	0.14286	0.0020	2.5	1.2500	0.0113	1.2387	1.1585	0.0076	1.1509	1.0670	0.0151	1.0519	15.2	7.6
1 3/8	6	0.16667	0.0021	2.3	1.5000	0.0122	1.4878	1.3933	0.0082	1.3851	1.2866	0.0163	1.2703	16.4	8.2
1 1/2	5	0.20000	0.0023	2.1	1.7500	0.0134	1.7366	1.6219	0.0089	1.6130	1.4939	0.0179	1.4760	17.8	8.9
2	4.5	0.22222	0.0025	2.0	2.0000	0.0141	1.9859	1.8577	0.0094	1.8483	1.7154	0.0189	1.6965	18.8	9.4
2 1/4	4	0.25000	0.0026	1.9	2.2500	0.0150	2.2350	2.0899	0.0100	2.0799	1.9208	0.0200	1.9008	20.0	10.0
2 1/2	4	0.25000	0.0026	1.9	2.5000	0.0150	2.4850	2.3399	0.0100	2.3299	2.1708	0.0200	2.1508	20.0	10.0
2 3/4	3.5	0.28571	0.0028	1.8	2.7500	0.0160	2.7340	2.5670	0.0107	2.5563	2.3841	0.0214	2.3627	21.4	10.7
3	3.5	0.28571	0.0028	1.8	3.0000	0.0160	2.9840	2.8170	0.0107	2.8063	2.6341	0.0214	2.6127	21.4	10.7

NOTE A.—Columns 4 and 5 give, for information, the errors in pitch per length of thread engaged and angle respectively, which can each be compensated by half the tolerance on effective diameter given in column 10. The errors in pitch and angle shown in the table may exist together, provided the effective diameter is reduced by the full tolerance shown in column 10. The permissible

FIG. 35.—BRITISH STANDARD WHITWORTH SCREW THREADS, STANDARD SIZES AND TOLERANCES—NUTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Nominal Diam. of Screw in Inches	No. of Threads per Inch	Pitch in Inches	Tolerances (See Note A)		Full Diameter in Inches			Effective Diameter in Inches			Core Diameter in Inches			Grade	Maximum Play Permissible
			Pitch in Inches	Angle, Degrees	Min.	Tol.	Max.	Min.	Tol.	Max.	Min.	Tol.	Max.	Thousandths of an Inch	Thousandths of an Inch
1/4	20	0.05000	0.0012	4.3	0.2520	0.0090	0.2610	0.2200	0.0045	0.2245	0.1880	0.0067	0.1947	9.0	4.5
5/16	18	0.05556	0.0012	4.0	0.3145	0.0094	0.3239	0.2780	0.0047	0.2836	0.2434	0.0071	0.2505	9.4	4.7
3/8	16	0.06250	0.0013	3.8	0.3770	0.0100	0.3870	0.3370	0.0050	0.3420	0.2970	0.0075	0.3045	10.0	5.0
7/16	14	0.07143	0.0014	3.5	0.4395	0.0107	0.4502	0.3938	0.0053	0.3991	0.3480	0.0080	0.3560	10.6	5.3
1/2	12	0.08333	0.0015	3.3	0.5020	0.0115	0.5135	0.4486	0.0058	0.4544	0.3953	0.0087	0.4040	11.6	5.8
9/16	12	0.08333	0.0015	3.3	0.5645	0.0115	0.5760	0.5111	0.0058	0.5169	0.4578	0.0087	0.4665	11.6	5.8
5/8	11	0.09091	0.0016	3.2	0.6270	0.0121	0.6391	0.5688	0.0060	0.5748	0.5106	0.0090	0.5196	12.0	6.0
3/4	10	0.10000	0.0016	3.0	0.7520	0.0126	0.7646	0.6880	0.0063	0.6943	0.6239	0.0095	0.6334	12.6	6.3
7/8	9	0.11111	0.0017	2.9	0.8770	0.0133	0.8903	0.8059	0.0067	0.8126	0.7347	0.0100	0.7447	13.4	6.7
1	8	0.12500	0.0018	2.7	1.0020	0.0141	1.0161	0.9220	0.0071	0.9291	0.8419	0.0106	0.8525	14.2	7.1
1 1/8	7	0.14286	0.0020	2.5	1.1270	0.0151	1.1421	1.0355	0.0076	1.0431	0.9440	0.0113	0.9553	15.2	7.6
1 1/4	7	0.14286	0.0020	2.5	1.2520	0.0151	1.2671	1.1605	0.0076	1.1681	1.0690	0.0113	1.0803	15.2	7.6
1 3/8	6	0.16667	0.0021	2.3	1.5020	0.0163	1.5183	1.3953	0.0082	1.4035	1.2886	0.0122	1.3008	16.4	8.2
1 1/2	5	0.20000	0.0023	2.1	1.7520	0.0179	1.7699	1.6239	0.0089	1.6328	1.4959	0.0134	1.5093	17.8	8.9
2	4.5	0.22222	0.0025	2.0	2.0020	0.0189	2.0209	1.8597	0.0094	1.8691	1.7174	0.0141	1.7315	18.8	9.4
2 1/4	4	0.25000	0.0026	1.9	2.2520	0.0200	2.2720	2.0919	0.0100	2.1019	1.9318	0.0150	1.9468	20.0	10.0
2 1/2	4	0.25000	0.0026	1.9	2.5020	0.0200	2.5220	2.3419	0.0100	2.3519	2.1818	0.0150	2.1968	20.0	10.0
2 3/4	3.5	0.28571	0.0028	1.8	2.7520	0.0214	2.7734	2.5690	0.0107	2.5797	2.3861	0.0160	2.4021	21.4	10.7
3	3.5	0.28571	0.0028	1.8	3.0020	0.0214	3.0234	2.8190	0.0107	2.8297	2.6361	0.0160	2.6521	21.4	10.7

NOTE A.—Columns 4 and 5 give, for information, the errors in pitch per length of thread engaged and angle respectively, which can each be compensated by half the tolerance on effective diameter given in column 10. The errors in pitch and angle shown in the table may exist together, provided the effective diameter is increased by the full tolerance shown in column 10. The permissible error in pitch may be increased up to double the value shown, provided the error in angle is correspondingly reduced, and *vice versa*.

BRITISH ASSOCIATION SCREW THREADS (B.A.)

British Association threads differ in every way from the British Standard or Whitworth thread, except that they are rounded at top and bottom. The angle is $47\frac{1}{2}$ degrees and metric measurements are used, the standard sizes in millimeters being rounded off in each case to the second significant figure after calculation from the formulae below:

Pitch in millimeters $= (0.9)^n$ when n is number designating the screw.

Diameters $= 6 \times \text{pitch}^{\frac{9}{8}}$

Roots and crests are rounded with equal radii such that the double depth of thread $= \frac{6}{5}$ pitch.

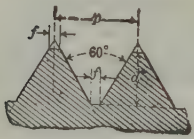
These are for screws smaller than $\frac{1}{4}$ inch similar to the American numbered series. The numbers, however, are opposite, No. 0 being the largest. The table follows:

TABLE 36.—BRITISH ASSOCIATION SCREW THREADS—47½-DEGREE ANGLE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Designating Number	Pitch, mm.	Approx. No. of Threads per Inch	Tolerances (See Note A)		Full Diameter, in Millimeters			Effective Diameter, in Millimeters			Core Diameter, in Millimeters			Grade	Maximum Play Permissible
			Pitch, Mm.	Angle, Deg.	Max.	Tol.	Min.	Max.	Tol.	Min.	Max.	Tol.	Min.	Hundredths of a mm.	Hundredths of a mm.
0	1.00	25.4	0.020	5.5	6.000	0.150	5.850	5.400	0.100	5.300	4.800	0.200	4.600	20.0	10.0
1	0.90	28.2	0.020	5.6	5.300	0.135	5.165	4.760	0.090	4.670	4.220	0.185	4.035	18.5	9.0
2	0.81	31.3	0.020	5.8	4.700	0.120	4.580	4.215	0.085	4.130	3.730	0.170	3.560	17.0	8.5
3	0.73	34.8	0.015	5.9	4.100	0.110	3.990	3.660	0.080	3.580	3.220	0.155	3.065	15.5	8.0
4	0.66	38.5	0.015	6.1	3.600	0.100	3.500	3.205	0.075	3.130	2.810	0.145	2.665	14.5	7.5
5	0.59	43.1	0.015	6.3	3.200	0.090	3.110	2.845	0.070	2.775	2.490	0.135	2.355	13.5	7.0
6	0.53	47.9	0.015	6.4	2.800	0.080	2.720	2.480	0.060	2.420	2.160	0.125	2.035	12.5	6.0
7	0.48	52.9	0.015	6.7	2.500	0.070	2.430	2.210	0.060	2.150	1.920	0.115	1.805	11.5	6.0
8	0.43	59.1	0.010	6.9	2.200	0.065	2.135	1.940	0.055	1.885	1.680	0.110	1.570	11.0	5.5
9	0.39	65.1	0.010	7.2	1.900	0.060	1.840	1.665	0.050	1.615	1.430	0.100	1.330	10.0	5.0
10	0.35	72.6	0.010	7.5	1.700	0.055	1.645	1.490	0.050	1.440	1.280	0.095	1.185	9.5	5.0
11	0.31	81.9	0.010	8.0	1.500	0.045	1.455	1.315	0.045	1.270	1.130	0.090	1.040	9.0	4.5
12	0.28	90.7	0.010	8.0	1.300	0.040	1.260	1.130	0.040	1.090	0.960	0.085	0.875	8.5	4.0
13	0.25	102.0	0.010	8.0	1.200	0.040	1.160	1.050	0.040	1.010	0.900	0.080	0.820	8.0	4.0
14	0.23	110.0	0.010	8.0	1.000	0.035	0.965	0.860	0.040	0.820	0.720	0.075	0.645	7.5	4.0
15	0.21	121.0	0.010	8.0	0.900	0.030	0.870	0.775	0.035	0.740	0.650	0.075	0.575	7.5	3.5

NOTE A.—Columns 4 and 5 give the errors in pitch per length of thread engaged and angle respectively, which can each be compensated by half the tolerance on effective diameter given in column 10. The errors in pitch and angle shown in the table may exist together, provided the effective diameter is reduced by the full tolerance shown in column 10. The permissible error in pitch may be increased up to double the value shown, provided the error in angle is correspondingly reduced and *vice versa*.

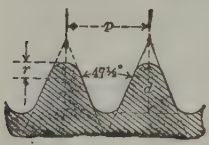
The leading thread forms now in use are:



American (National) Standard—

p = pitch
d = depth = $p \times .6495$
f = flat = $\frac{p}{8}$

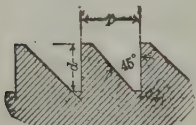
This thread was devised by Wm. Sellers and recommended by the Franklin Institute.



British Association Standard—

p = pitch
d = depth = $p \times 0.6$
r = radius = $\frac{2 \times p}{11}$

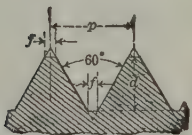
This thread has been adopted in England for small screws used by opticians and in telegraph work, upon recommendation made by the committtee of the British Association. It was derived from the Swiss thread of Prof. Thury. The diameter and pitches in this system are in millimeters.



Buttress—

p = pitch = $\frac{1}{\text{no. threads per inch}}$
d = depth = $\frac{3}{4}\ p$

The buttress thread takes a bearing only on the straight side and is very strong in that direction. The ratchet thread is of practically the same form but sharper.



International (Metric) Standard—

p = pitch
d = depth = $p \times 0.6495$
f = flat = $\frac{p}{8}$

The International thread is of the same form as the American. This system was recommended by a Congress held at Zurich in 1898, and is much the same as the metric system of threads generally used in France. The sizes and pitches in the system are in millimeters.

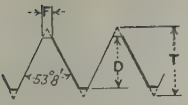


Square—

p = pitch = $\frac{1}{\text{no. threads per inch}}$
d = depth = $\frac{1}{2}\ p$
f = width of flat = $\frac{1}{2}\ p$
s = width of space = $\frac{1}{2}\ p$.

While theoretically depth, width of space and thread are each one-half the pitch, in practice the groove is cut slightly wider and deeper.

Lowenherz-German—

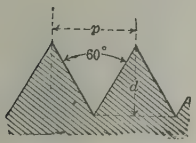


Used on the Continent for fine work. Pitch in millimeters

$D = \frac{3}{4} T$

F = flat = 0.0049 × pitch in millimeters.

V, 60-degree Sharp—

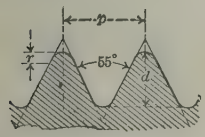


p = pitch = $\frac{1}{\text{no. threads per inch}}$

d = depth = $p \times 0.8660$

While the sharp V form gives a deeper thread than the U. S. Standard, the objections urged against the thread are that the sharp top is injured by the slightest accident, and, in the case of taps and dies, the fine edge is quickly lost, causing constant variation in fitting.

Whitworth Standard—



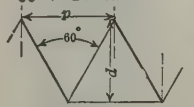
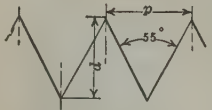
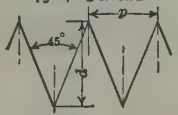
p = pitch = $\frac{1}{\text{no. threads per inch}}$

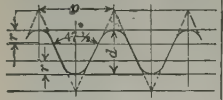
d = depth = $p \times 0.64033$

r = radius = $p \times 0.1373$

The Whitworth thread is the standard in use in England. It was devised by Sir Joseph Whitworth in 1841, the system then proposed by him being slightly modified in 1857 and 1861.

PROPERTIES OF WATCH SCREW THREADS

60° V-Thread 	Theoretical formulæ $P = \frac{1}{\text{No. of threads}}$ $d = P \times .866$	Theoretical formulæ for double depth $d = \frac{1.732}{\text{No. of threads}}$	Working formulæ for double depth $d = \frac{1.4}{\text{No. of threads}}$	Used by E. Howard for machine shop screws and for 240 and 320 threads per inch special watch screws. This was old standard but is being replaced by U. S. form of thread.
55° V-Thread 	$P = \frac{1}{\text{No. of threads}}$ $d = P \times .9605$	$d = \frac{1.92098}{\text{No. of threads}}$	$d = \frac{1.532}{\text{No. of threads}}$	New York Standard Watch Works screw thread.
45° V-Thread 	$P = \frac{1}{\text{No. of threads}}$ $D = P \times 1.2071$	$d = \frac{2.4142}{\text{No. of threads}}$	$d = \frac{1.732}{\text{No. of threads}}$	E. Howard watch screws. Used in most American watch factories.

Thury's Swiss Thread 	$P = \frac{1}{\text{No. of threads}}$ $d = P \times .6$ $r = \frac{P}{6}$ $r' = \frac{P}{5}$	$d = \frac{1.2}{\text{No. of threads}}$	$d = \frac{1.15}{\text{No. of threads}}$	Developed by Prof. Thury of Geneva, Switzerland. Used for Swiss watch stems, also for some watch screws. E. Howard used for balance screws. Keystone Watch Case Co. uses U. S. form of thread for stems. British association thread, page 19 is similar to Prof. Thury's thread and is used in England, for clocks and small instruments.

Working formulæ are approximate for small threads.

PIPE AND PIPE THREADS

AMERICAN STANDARD PIPE THREADS

The American or Briggs Pipe Thread Standard was formulated by Robert Briggs prior to 1882. It has been modified to conform to pitch diameter instead of outside diameter, and the tables now given have been approved by the leading technical associations, through the American Engineering Standard Committee. Although the tables and illustrations appear quite different than in previous editions, the essential dimensions are very similar.

The taper is 1 to 16 inches, or $\frac{3}{4}$ inch per foot. The thread angle is 60 degrees measured from the axis of the pipe. Mr. Briggs originally advocated rounding the threads, but they are slightly flattened to 0.033 of the pitch instead. The formula now gives the *effective* length of thread, that includes two threads slightly imperfect, while the old formula gave the length of *perfect* threads, see Fig. 1.

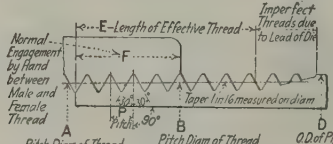


FIG. 1.—Standard Notations, See Table 1

Diameter of Taper Thread.—The pitch diameters of the taper thread are determined by formulas based on the outside diameter of pipe and the pitch of thread. These are as follows:

$$A = D - (0.050D + 1.1)P \quad B = A + 0.0625F$$

where A = pitch diameter of thread at end of pipe.
B = pitch diameter of thread at gaging notch.
D = outside diameter of pipe.
F = normal engagement by hand between external and internal threads.
P = pitch of thread.

Length of Thread.—The length of the taper external or male thread is determined by a formula based on the outside diameter of the pipe and the pitch of the thread. This is as follows:

$$E = (0.80D + 6.8)P$$

where E = length of effective thread.
D = outside diameter of pipe.
P = pitch of thread.

Depth of thread = 0.80 P

For engagement of threads, see F in Table 1.

DIAGRAM SHOWING NOTATION OF AMERICAN STANDARD TAPER PIPE THREAD (See Table 1)

$$A = D - (0.05D + 1.1)P$$
$$B = A + 0.0625F$$
$$E = (0.80D + 6.8)P$$
Depth of thread = $0.80P$

Gages and Methods of Gaging

Gages to maintain interchangeability of product properly should consist of master gages, reference gages used for checking working gages (see Figs. 2, 3 and 4) and working gages used for checking the product. The dimensions and use of these gages are described below.

Master Gage.—The master gage is a taper-threaded plug gage. This should be accompanied by two taper threaded ring gages (known as checks) to afford ready comparisons. The plug gage is made to the dimensions given in Table 1, and shown in the diagram and in Figs. 2, 3 and 4. It includes the gaging notch, or the difference between E and F in Table 1.

One ring (check) has a thickness equal to dimension F, is the same diameter at the small end as the small end of the plug gage and is flush with the plug gage at the small end and at the gaging notch when screwed on tight by hand (see Fig. 2). This check will be fitted to its master.

The other ring (check) has a thickness equal to dimension E, but is threaded for a distance equal to E minus F. It is the same diameter at the large end as the large end of the plug gage. The distance equal to F is counterbored and unthreaded (see Fig. 3). This check will also be fitted to its master.

The roots of the threads are cut to a sharp V, or may be undercut beyond the sharp V to facilitate making the thread (see Fig. 4). The crests are truncated* an amount equal to $0.1P$, as illustrated in Fig. 4.

Master gages and their checks are primarily for the use of gage and thread-tool manufacturers, and for very accurate reference in checking gages.

Reference Gage.—The reference gage consists of one taper-threaded plug gage and two taper-threaded ring gages. The plug gage is made to the dimensions given in Table 1, and shown in Figs. 2, 3 and 4. It includes the gaging notch.

One ring gage has a thickness equal to dimension F, is the same diameter at the small end as the small end of the plug gage and is

* The object of truncating the crests on gages (truncation $0.1P$) is to insure that, when gaging a commercial thread cut with a slightly dull tool, the gage bears on the sides of the thread instead of on the roots.

flush with the plug gage at the small end and at the gaging notch when screwed on tight by hand (see Fig. 2).

The other ring gage has a thickness equal to dimension E, but is threaded for a distance equal to E minus F. It is the same diameter at the large end as the large end of the plug gage. The distance equal to F is counterbored and unthreaded (see Fig. 3).

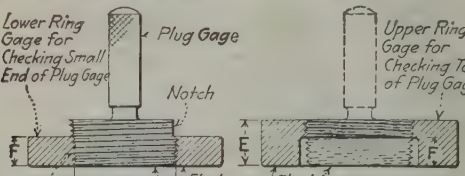


FIG. 2 FIG. 3

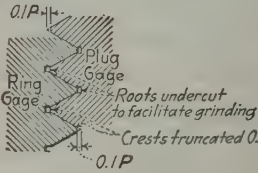


FIG. 4

Reference Gages for Checking Working Gages

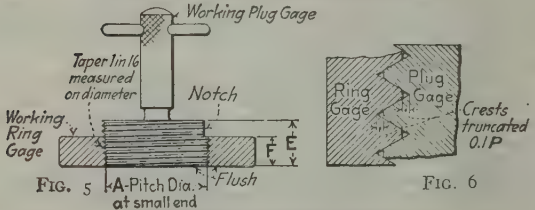


FIG. 5 FIG. 6

Working Gages for Checking Product

FIGS. 2 to 6

Working Gage.—The working gage consists of one taper-threaded plug gage and one taper-threaded ring gage. The plug gage is made to the dimensions given in Table 1, and shown in Figs. 5 and 6. It includes the gaging notch.

The ring gage has a thickness equal to dimension F, and is the same diameter at the small end as the small end of the plug gage (see Fig. 5).

The crests are truncated an amount equal to $0.1P$. The roots are cut to a sharp V, or may be undercut beyond the sharp V to facilitate making the thread (see Fig. 6).

Gaging Taper External Threads.—In gaging external or male threads, the ring gage, Fig. 5, should screw tight by hand on the pipe or male thread until the small end of the gage is flush with the end of the thread (see Fig. 7).

Gaging Taper Internal Threads.—In gaging internal or female threads, the plug gage, Fig. 5, should screw tight by hand into the fitting or coupling until the notch is flush with the face. When the thread is chamfered, the notch should be flush with the bottom of the chamfer.

This method of gaging is used either for taper internal (female) threads or for straight threaded couplings which screw together with taper external (male) threads (see Figs. 10 and 13).

GAGE AND WORKING TOLERANCES

Gage Tolerances.—In the manufacture of gages, variations from basic dimensions are unavoidable. Furthermore, gages will wear in use. In order to fix the maximum allowable variations of gages, tolerances have been established.

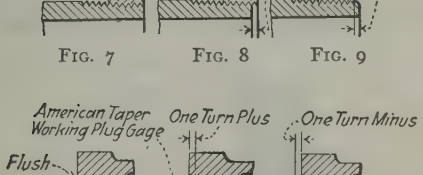


FIG. 7 FIG. 8 FIG. 9

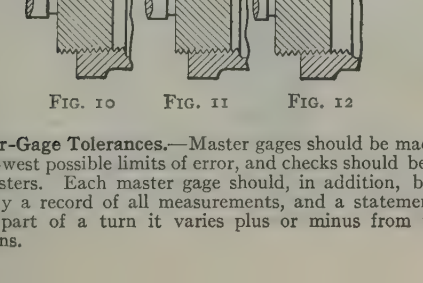


FIG. 10 FIG. 11 FIG. 12

Master-Gage Tolerances.—Master gages should be made within the narrowest possible limits of error, and checks should be fitted to their masters. Each master gage should, in addition, be accompanied by a record of all measurements, and a statement of the decimal part of a turn it varies plus or minus from the basic dimensions.

Table 2 column 1, is used when checking gages by measurement. No point on the thread surface of the gage should be outside of the zone of tolerance indicated by the shaded portion of the illustration.

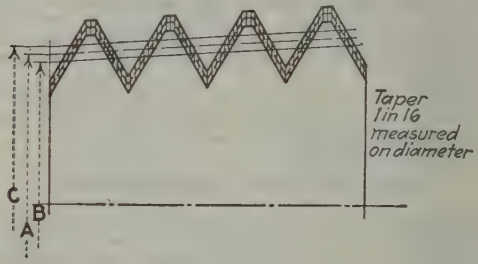


Diagram of Pipe Gage Thread

The dotted line indicates the outline of a perfect gage made exactly to the basic dimensions.

A = basic pitch diameter at small end of gage.
B = minimum pitch diameter at small end of gage.
C = maximum pitch diameter at small end of gage.
$B = A -$ Column 1 from Table 2 for reference gages.
$C = A +$ Column 1 from Table 2 for reference gages.

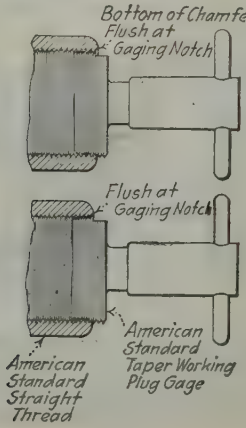


FIG. 13

Column 2 gives the equivalent of column 1, expressed in terms of distance parallel to the axis, and represents the maximum distance that a reference ring gage of perfect thickness or a reference plug gage of perfect length from small end to gaging notch may vary from being flush at the gaging notch or at the small end, when referred to basic dimensions. It is equal to 16 times column 1, owing to the basic taper of 1 in 16, measured on the diameter. This column is used when checking reference gages by comparison with a master gage. The necessary allowance must be made, of course, for the error in the master.

Column 3 gives the equivalent of column 2, expressed in terms of the decimal part of a turn from the basic dimensions. This column is also used when checking reference gages by comparison with a master gage. In this operation the necessary allowance must be made for the error in the master.

A tolerance of plus or minus 0.0002 inch (0.005 millimeter) is allowed on the distance between the gaging notch and the small end of the reference plug gage, or on the thickness of the reference ring gage. It is possible for reference plug and ring gages which come within all of the above tolerances to vary from being flush with each other at the small end, or at the gaging notch, when screwed together tightly by hand. The maximum variation which might occur, expressed in terms of distance, is given in column 4, and gages which come within these limits should be checked by measurement before being rejected. Working gage tolerance is twice the tolerance allowed in the reference gages.

Manufacturing Tolerances.—The maximum allowable variation in the commercial product is one turn plus or one turn minus from the gaging notch when using working gages (see Figs. 8, 9, 11 and 12). This is equivalent to a maximum allowable variation of one and one-half turns from the basic dimensions, owing to the allowance of one-half turn on working gages.

STRAIGHT THREAD AND ITS USES

While the taper external and internal threads are recommended for threaded joints for every service, there are certain uses for a straight pipe thread. Straight threaded female wrought-iron or wrought-steel couplings of the weight known as "standard" may be used with taper-threaded pipe for ordinary pressures, as they are sufficiently ductile to adjust themselves to the taper male thread when properly screwed together. (For dimensions, see Table 4.) For high pressures, however, only taper-threaded pipe and fittings should be used.

Straight male threads are recognized only for special applications, such as long screws and tank nipples.

In gaging, the American taper working plug gage is used, allowing the same tolerance from the notch as for a taper thread (see Fig. 13). The straight thread on the pipe enters the coupling freely by hand, the joint being made by a packing material between the locknut and the coupling.

TABLE 1.—DIMENSIONS OF AMERICAN STANDARD TAPER PIPE THREAD. SEE FIG. 1

Nominal Size		A		B		E		F		D		Depth of Thread		Number of Threads	
Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Per Inch	Per 254 Millimeters
⅛	3	0.36351	9.233	0.37476	9.519	0.2638	6.700	0.180	4.572	0.405	10.287	0.02963	0.753	27	270
¼	6	0.47739	12.126	0.48689	12.443	0.4018	10.206	0.200	5.080	0.540	13.716	0.04444	1.129	18	180
⅜	10	0.61201	15.545	0.62701	15.926	0.4078	10.358	0.240	6.096	0.675	17.145	0.04444	1.129	18	180
½	13	0.75843	19.264	0.77843	19.772	0.5337	13.556	0.320	8.128	0.840	21.336	0.05714	1.451	14	140
¾	19	0.96768	24.579	0.98886	25.117	0.5457	13.861	0.339	8.611	1.050	26.670	0.05714	1.451	14	140
1	25	1.21363	30.826	1.23863	31.461	0.6828	17.343	0.400	10.160	1.315	33.401	0.06956	1.767	11½	115
1¼	32	1.55713	39.551	1.58338	40.218	0.7068	17.953	0.420	10.668	1.660	42.164	0.06956	1.767	11½	115
1½	38	1.79609	45.621	1.82234	46.287	0.7235	18.377	0.420	10.668	1.900	48.260	0.06956	1.767	11½	115
2	50	2.26902	57.633	2.29627	58.325	0.7505	19.215	0.436	11.074	2.375	60.235	0.06956	1.767	11½	115
2½	64	2.71953	69.076	2.76216	70.159	1.1375	28.892	0.682	17.323	2.875	72.025	0.10000	2.540	8	80
3	76	3.34063	84.852	3.38850	86.068	1.2000	30.480	0.766	19.456	3.500	88.900	0.10000	2.540	8	80
3½	90	3.83750	97.473	3.88881	98.776	1.2500	31.750	0.821	20.853	4.000	101.600	0.10000	2.540	8	80
4	100	4.33438	110.093	4.38713	111.433	1.3000	33.020	0.844	21.438	4.500	114.300	0.10000	2.540	8	80
4½	113	4.83125	122.714	4.88594	124.103	1.3500	34.290	0.875	22.225	5.000	127.000	0.10000	2.540	8	80
5	125	5.39073	136.925	5.44929	138.412	1.4063	35.720	0.937	23.800	5.563	141.300	0.10000	2.540	8	80
6	150	6.44609	163.731	6.50597	165.252	1.5125	38.417	0.958	24.333	6.625	168.275	0.10000	2.540	8	80
7	175	7.43984	188.972	7.50234	190.560	1.6125	40.957	1.000	25.400	7.625	193.675	0.10000	2.540	8	80
8	200	8.43359	214.214	8.50003	215.901	1.7125	43.497	1.003	27.000	8.625	219.075	0.10000	2.540	8	80
9	225	9.42734	239.455	9.49797	241.249	1.8125	46.037	1.130	28.702	9.625	244.475	0.10000	2.540	8	80
10	250	10.54531	267.851	10.62094	269.772	1.9250	48.895	1.210	30.734	10.750	273.050	0.10000	2.540	8	80
11	275	11.53906	293.093	11.61938	295.133	2.0250	51.435	1.285	32.639	11.750	298.450	0.10000	2.540	8	80
12	300	12.53281	318.334	12.61781	320.493	2.1250	53.975	1.360	34.544	12.750	323.851	0.10000	2.540	8	80
14 O.D.	350	13.77500	349.886	13.87262	352.305	2.250	57.150	1.562	39.675	14.000	355.601	0.10000	2.540	8	80
15 O.D.	375	14.76875	375.127	14.87419	377.805	2.350	59.690	1.687	42.850	15.000	381.001	0.10000	2.540	8	80
16 O.D.	400	15.76250	400.368	15.87575	403.245	2.450	62.230	1.812	46.025	16.000	406.401	0.10000	2.540	8	80
17 O.D.	425	16.75625	425.609	16.87500	428.626	2.550	64.770	1.900	48.260	17.000	431.801	0.10000	2.540	8	80
18 O.D.	450	17.75000	450.851	17.87500	454.026	2.650	67.310	2.000	50.800	18.000	457.201	0.10000	2.540	8	80
20 O.D.	500	19.73750	501.333	19.87031	504.707	2.850	72.390	2.125	53.975	20.000	508.001	0.10000	2.540	8	80
22 O.D.	550	21.72500	551.816	21.86562	555.388	3.050	77.470	2.250	57.150	22.000	558.801	0.10000	2.540	8	80
24 O.D.	600	23.71250	602.299	23.86094	606.069	3.250	82.550	2.375	60.325	24.000	609.601	0.10000	2.540	8	80
26 O.D.	650	25.70000	652.781	25.85625	656.750	3.450	87.630	2.500	63.500	26.000	660.401	0.10000	2.540	8	80
28 O.D.	700	27.68750	703.264	27.85156	707.431	3.650	92.710	2.625	66.675	28.000	711.201	0.10000	2.540	8	80
30 O.D.	750	29.67500	753.746	29.84687	758.113	3.850	97.790	2.750	69.850	30.000	762.001	0.10000	2.540	8	80

TABLE 2.—TOLERANCES FOR REFERENCE GAGES

Nominal Size		1 Total Cumulative Tolerance on Diameter (see Fig. 16)		2 Equivalent Longitudinal Variation (16 × column 1)		3 Equivalent Angular Variation Expressed as Decimal Part of One Turn	4 Variations in Distance*	
Inches	Millimeters	Inches	Millimeters	Inches	Millimeters		Inches	Millimeters
⅛	3	0.00020	0.0050	0.0032	0.081	0.086	0.0068	0.173
¼	6	0.00022	0.0056	0.0035	0.089	0.063	0.0074	0.188
⅜	10	0.00024	0.0061	0.0038	0.097	0.068	0.0080	0.203
½	13	0.00026	0.0066	0.0042	0.107	0.059	0.0088	0.224
¾	19	0.00028	0.0071	0.0045	0.114	0.063	0.0094	0.239
1	25	0.00030	0.0076	0.0048	0.122	0.055	0.0100	0.254
1¼	32	0.00032	0.0081	0.0051	0.130	0.059	0.0106	0.269
1½	38	0.00034	0.0086	0.0054	0.137	0.062	0.0112	0.284
2	50	0.00036	0.0091	0.0058	0.147	0.067	0.0120	0.305
2½	64	0.00038	0.0097	0.0061	0.155	0.050	0.0126	0.320
3	76	0.00038	0.0097	0.0061	0.155	0.050	0.0126	0.320
3½	90	0.00041	0.0104	0.0066	0.168	0.053	0.0136	0.345
4	100	0.00043	0.0109	0.0069	0.175	0.055	0.0142	0.361
4½	113	0.00045	0.0114	0.0072	0.183	0.058	0.0148	0.376
5	125	0.00047	0.0119	0.0075	0.191	0.060	0.0154	0.391
6	150	0.00051	0.0130	0.0082	0.208	0.065	0.0168	0.427
7	175	0.00055	0.0140	0.0088	0.224	0.070	0.0180	0.457
8	200	0.00069	0.0150	0.0094	0.239	0.075	0.0192	0.488
9	225	0.00063	0.0160	0.0101	0.257	0.080	0.0206	0.523
10	250	0.00066	0.0168	0.0106	0.269	0.085	0.0216	0.549
12	300	0.00074	0.0188	0.0118	0.300	0.095	0.0240	0.610
14	350	0.00082	0.0208	0.0131	0.333	0.105	0.0266	0.676
16	400	0.00090	0.0229	0.0144	0.366	0.115	0.0292	0.742
18	450	0.00098	0.0249	0.0157	0.399	0.125	0.0318	0.808
20	500	0.00106	0.0269	0.0170	0.432	0.135	0.0344	0.874
22	550	0.00113	0.0287	0.0181	0.460	0.145	0.0366	0.930
24	600	0.00121	0.0307	0.0194	0.493	0.155	0.0392	0.996
26	650	0.00129	0.0328	0.0206	0.523	0.165	0.0416	1.057
28	700	0.00137	0.0348	0.0219	0.556	0.175	0.0442	1.123
30	750	0.00144	0.0366	0.0230	0.584	0.185	0.0464	1.179

* Maximum amount it is possible for plug and ring gages to vary from being flush at small end or at gaging notch when screwed together tight by hand. (2 times column 2 + 0.0004 inch.)

TABLE 3.—DIMENSION OF STANDARD PIPE

Nominal Size		Inside Diameter		External Diameter		Nominal Thickness		Transverse Areas				Length of Pipe per Sq. Ft. of External Surface		Length of Pipe per Sq. M. of External Surface		Nominal Weight per Ft. Threaded and Coupled	Nominal Weight per M. Threaded and Coupled
								Internal			Metal						
Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Sq. Inches	Sq. Millimeters	Sq. Inches	Sq. Millimeters	Feet	Meters	Pounds	Kilograms		
⅛	3	0.269	6.833	0.405	10.287	0.068	1.727	0.057	36.77	0.072	46.45	9.431	30.94	0.245	0.364		
¼	6	0.364	9.246	0.540	13.716	0.088	2.235	0.104	67.10	0.125	80.64	7.073	23.20	0.425	0.632		
⅜	10	0.493	12.522	0.675	17.145	0.091	2.311	0.191	123.23	0.167	107.74	5.658	18.56	0.568	0.845		
½	13	0.622	15.799	0.840	21.336	0.109	2.769	0.304	196.13	0.250	161.29	4.547	14.91	0.852	1.268		
¾	19	0.824	20.930	1.050	26.670	0.113	2.870	0.533	343.87	0.333	214.84	3.637	11.93	1.134	1.687		
1	25	1.049	26.645	1.315	33.401	0.133	3.378	0.864	557.42	0.494	318.71	2.904	9.53	1.684	2.506		
1¼	32	1.380	35.052	1.660	42.164	0.140	3.556	1.495	964.52	0.669	431.61	2.301	7.55	2.281	3.394		
1½	38	1.610	40.894	1.900	48.260	0.145	3.683	2.036	1313.55	0.799	515.48	2.010	6.59	2.731	4.064		
2	50	2.067	52.502	2.375	60.325	0.154	3.912	3.355	2164.52	1.075	693.55	1.608	5.27	3.678	5.473		
2½	64	2.469	62.713	2.875	73.025	0.203	5.156	4.788	3089.04	1.704	1099.36	1.328	4.36	5.819	8.660		
3	76	3.068	77.927	3.500	88.900	0.216	5.486	7.393	4769.69	2.228	1437.42	1.091	3.58	7.616	11.334		
3½	90	3.548	90.119	4.000	101.600	0.226	5.740	9.886	6378.08	2.680	1729.03	0.954	3.13	9.202	13.694		
4	100	4.026	102.261	4.500	114.300	0.237	6.020	12.730	8212.92	3.174	2047.74	0.848	2.78	10.889	16.204		
4½	113	4.506	114.453	5.000	127.000	0.247	6.274	15.947	10288.41	3.688	2379.35	0.763	2.50	12.642	18.813		

5	125	5.047	128.194	5.563	141.300	0.258	6.553	20.006	12907.12	4.300	2774.20	0.686	2.25	14.810	22.040
6	150	6.065	154.051	6.625	168.275	0.280	7.112	28.891	18639.30	5.581	3600.65	0.576	1.89	19.185	28.550
7	175	7.023	178.385	7.625	193.675	0.301	7.645	38.738	24992.31	6.926	4468.39	0.500	1.64	23.769	35.372
8	200	8.071	205.004	8.625	219.075	0.277	7.036	51.101	33007.16	7.205	4687.10	0.442	1.45	25.000	37.204
8	200	7.981	202.718	8.625	219.075	0.322	8.179	50.027	32275.55	8.390	5418.72	0.442	1.45	28.809	42.872
9	225	8.941	227.102	9.625	244.475	0.342	8.687	62.786	40507.17	9.974	6434.85	0.396	1.30	34.188	50.877
10	250	10.192	258.877	10.750	273.050	0.279	7.087	81.585	52635.58	9.178	5921.30	0.355	1.16	32.000	47.621
10	250	10.136	257.455	10.750	273.050	0.307	7.798	80.691	52058.81	10.072	6498.08	0.355	1.16	35.000	52.086
10	250	10.020	254.508	10.750	273.050	0.365	9.271	78.855	50874.29	11.968	7682.59	0.355	1.16	41.132	61.211
11	275	11.000	279.400	11.750	298.450	0.375	9.525	95.033	61311.73	13.401	8645.82	0.325	1.07	46.247	68.823
12	300	12.090	307.087	12.750	323.851	0.330	8.382	114.800	74064.66	12.876	8307.11	0.299	0.98	45.000	66.967
12	300	12.000	304.801	12.750	323.851	0.375	9.525	113.097	72965.93	14.579	9405.82	0.299	0.98	50.706	75.459

TABLE 4.—DIMENSIONS OF AMERICAN STANDARD STRAIGHT PIPE THREAD

Nominal Size		B		Depth of Thread		Number of Threads	
Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Per Inch	Per 254 Millimeters
⅛	3	0.37476	9.519	0.02963	0.753	27	270
¼	6	0.48989	12.443	0.04444	1.129	18	180
⅜	10	0.62701	15.926	0.04444	1.129	18	180
½	13	0.77843	19.772	0.05714	1.451	14	140
¾	19	0.98886	25.117	0.05714	1.451	14	140
1	25	1.23863	31.461	0.06956	1.767	11½	115
1¼	32	1.58338	40.218	0.06956	1.767	11½	115
1½	38	1.82234	46.287	0.06956	1.767	11½	115
2	50	2.29627	58.325	0.06956	1.767	11½	115
2½	64	2.76216	70.159	0.10000	2.540	8	80
3	76	3.38850	86.068	0.10000	2.540	8	80
3½	90	3.88881	98.776	0.10000	2.540	8	80
4	100	4.38713	111.433	0.10000	2.540	8	80
4½	113	4.88504	124.103	0.10000	2.540	8	80
5	125	5.44929	138.412	0.10000	2.540	8	80
6	150	6.50597	165.252	0.10000	2.540	8	80
7	175	7.50234	190.560	0.10000	2.540	8	80
8	200	8.50003	215.901	0.10000	2.540	8	80
9	225	9.49797	241.249	0.10000	2.540	8	80
10	250	10.62094	269.772	0.10000	2.540	8	80
11	275	11.61938	295.133	0.10000	2.540	8	80
12	300	12.61781	320.493	0.10000	2.540	8	80
14 O.D.	350	13.87262	352.365	0.10000	2.540	8	80
15 O.D.	375	14.87419	377.805	0.10000	2.540	8	80
16 O.D.	400	15.87575	403.245	0.10000	2.540	8	80
17 O.D.	425	16.87500	428.626	0.10000	2.540	8	80
18 O.D.	450	17.87500	454.026	0.10000	2.540	8	80
20 O.D.	500	19.87031	504.707	0.10000	2.540	8	80
22 O.D.	550	21.86562	555.388	0.10000	2.540	8	80
24 O.D.	600	23.86094	606.069	0.10000	2.540	8	80
26 O.D.	650	25.85625	656.758	0.10000	2.540	8	80
28 O.D.	700	27.85156	707.431	0.10000	2.540	8	80
30 O.D.	750	29.84687	758.112	0.10000	2.540	8	80

TABLE 5.—DRILL SIZES FOR AMERICAN TAPER PIPE TAPS FOR TAPPING WITHOUT REAMING

Size of Pipe	Threads per Inch	Root Diam. Small End of Tap in Inches	Root Diam. Small End of Pipe and Gage in Inches	Tap Drill	
				Size	Decimal Equivalent
$\frac{1}{8}$	27	0.3145	0.3339	R	0.339
$\frac{1}{4}$	18	0.4043	0.4329	$\frac{7}{16}$	0.437
$\frac{3}{8}$	18	0.5393	0.5676	$\frac{37}{64}$	0.578
$\frac{1}{2}$	14	0.6651	0.7013	$\frac{23}{32}$	0.719
$\frac{3}{4}$	14	0.8751	0.9105	$\frac{59}{64}$	0.921
1	$11\frac{1}{2}$	1.1017	1.1441	$1\frac{5}{32}$	1.156
$1\frac{1}{4}$	$11\frac{1}{2}$	1.4447	1.4876	$1\frac{1}{2}$	1.500
$1\frac{1}{2}$	$11\frac{1}{2}$	1.6828	1.7265	$1\frac{47}{64}$	1.734
2	$11\frac{1}{2}$	2.1578	2.1995	$2\frac{7}{32}$	2.218
$2\frac{1}{2}$	8	2.5617	2.6195	$2\frac{1}{2}$	2.625
3	8	3.1828	3.2406	$3\frac{1}{4}$	3.250
$3\frac{1}{2}$	8	3.6789	3.7375	$3\frac{3}{4}$	3.750
4	8	4.1750	4.2344	$4\frac{1}{4}$	4.250

BRASS TUBE SIZES FOR CHANDELIER WORK

TABLE 6.—TUBING, JOINTS AND FITTINGS FOR CHANDELIERS ARE OF THE FOLLOWING SIZES

Outside Diameter or Trade Name	Outside Diameter of Thread	Number of Threads to the Inch
$\frac{1}{4}$	0.265	27
$\frac{5}{16}$	0.327	27
$\frac{3}{8}$	0.390	27
$\frac{7}{16}$	0.452	27
$\frac{1}{2}$	0.515	27
$\frac{9}{16}$	0.577	27
$\frac{5}{8}$	0.640	27
$\frac{3}{4}$	0.765	27

French chandelier work uses tubing 11 millimeters (0.433 inch) in diameter, with a thread of 1.3-millimeter pitch, (0.05 inch or about 20 theads per inch).

TABLE 7.—DIMENSIONS OF AMERICAN STANDARD LOCKNUT THREAD

Nominal Size		C		G		Depth of Thread		Number of Threads	
Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Per Inch	Per 254 Millimeters
⅛	3	0.38402	9.754	0.38633	9.813	0.02963	0.753	27	270
¼	6	0.50378	12.796	0.50725	12.884	0.04444	1.129	18	180
⅜	10	0.64090	16.279	0.64437	16.367	0.04444	1.129	18	180
½	13	0.79628	20.225	0.80075	20.339	0.05714	1.451	14	140
¾	19	1.00672	25.571	1.01118	25.684	0.05714	1.451	14	140
1	25	1.26037	32.013	1.26580	32.151	0.06956	1.767	11½	115
1¼	32	1.60512	40.770	1.61055	40.908	0.06956	1.767	11½	115
1½	38	1.84407	46.839	1.84951	46.978	0.06956	1.767	11½	115
2	50	2.31801	58.877	2.32344	59.015	0.06956	1.767	11½	115
2½	64	2.79341	70.953	2.80122	71.151	0.10000	2.540	8	80
3	76	3.41975	86.862	3.42756	87.060	0.10000	2.540	8	80
3½	90	3.92006	99.570	3.92787	99.768	0.10000	2.540	8	80
4	100	4.41838	112.227	4.42619	112.425	0.10000	2.540	8	80
4½	113	4.91719	124.897	4.92500	125.095	0.10000	2.540	8	80
5	125	5.48054	139.206	5.48836	139.405	0.10000	2.540	8	80
6	150	6.53722	166.046	6.54503	166.244	0.10000	2.540	8	80
7	175	7.53359	191.354	7.54141	191.552	0.10000	2.540	8	80
8	200	8.53128	216.695	8.53909	216.893	0.10000	2.540	8	80
9	225	9.52922	242.043	9.53703	242.241	0.10000	2.540	8	80
10	250	10.65219	270.566	10.66000	270.764	0.10000	2.540	8	80
11	275	11.65063	295.927	11.65844	296.125	0.10000	2.540	8	80
12	300	12.64906	321.287	12.65688	321.485	0.10000	2.540	8	80

PIPE USED IN OIL-WELL WORK

AMERICAN PETROLEUM INSTITUTE STANDARD

Steel for butt-welded line pipe, drive pipe, casing and tubing may be made by Bessemer open-hearth or electric process if of good welding quality. For lap-welded drill pipe, open-hearth steel is used, while for seamless drill pipe it may be either open-hearth or electric.

American standard-form threads are used, except that threads on pipe for rotary drilling may be rounded to 0.017 inch radius on 8 pitch instead of being flattened. Three tapers are used, these being given in Table 8 together with the tolerances.

TABLE 8.—TAPERS AND TOLERANCES

	When taper per foot is specified as:		
	$\frac{1}{16}$ Inch	$\frac{1}{8}$ Inch	$\frac{1}{4}$ Inch
Maximum taper, inches	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{13}{16}$
Minimum taper, inches	$\frac{5}{32}$	$\frac{11}{32}$	$\frac{23}{32}$

Several dimensions for oil-well casings are given in Table 9.

TABLE 9.—AMERICAN PETROLEUM INSTITUTE CASING
"Size" of A. P. I. casing indicates outside diameter

Size	Diameters in Inches			Thickness	Weight per Foot in Pounds				Threads per Inch	Coupling in Inches				Depth in Feet for Compression Factor of Safety of 2 for Lap Weld Steel
	External	Internal	Upset		Plain Ends	Threads and Couplings	Upset Casing without Couplings	Upset Casing with Threads and Couplings		Diameter for Casing Not Upset	Length	Diameter for Upset Casing	Width of Bearing Face	
*4¼	4.75	4.082		0.334	15.752	16.00			10	5.364	6⅝		3/16	5,420
4¼	4.75	4.082	5	0.334			16.03	16.25	10		7	5.65	3/16	5,420
5¼	5.75	5.29		0.23	13.56	14.00			10	6.5625	7½		¼	2,390
5¼	5.75	5.19		0.28	16.36	17.00			10	6.5625	7½		¼	3,260
5¼	5.75	5.09		0.33	19.10	19.50			10	6.5625	7½		¼	4,130
5¼	5.75	5.09	6	0.33			19.36	20.00	10		8½	6.75	¼	4,130
5¼	5.75	4.99		0.38	21.80	22.50			10	6.5625	7½		¼	5,000
5¼	5.75	4.99	6	0.38			22.16	23.00	10		8½	6.75	¼	5,000
*6⅝	6.625	6.049		0.288	19.491	20.00			10	7.390	7⅝		¼	2,740
*6⅝	6.625	5.921		0.352	23.582	24.00			10	7.390	7⅝		¼	3,710
*6⅝	6.625	5.855		0.385	25.658	26.00			10	7.390	7⅝		¼	4,200
*6⅝	6.625	5.791		0.417	27.648	28.00			10	7.390	7⅝		¼	4,690
8¼	8.125	7.485		0.32	26.68	28.00			10	9.0037	8½		¼	2,330
8¼	8.125	7.385		0.37	30.65	32.00			10	9.0037	8½		¼	2,940
8¼	8.125	7.285		0.42	34.56	35.50			10	9.0037	8½		¼	3,560
8¼	8.125	7.185		0.47	38.42	39.50			10	9.0037	8½		¼	4,180
8¼	8.125	7.185	8.375	0.47			38.80	40.00	10		8½	9.30	¼	4,180
*8⅝	8.625	8.017		0.304	27.016	28.00			10	9.593	8⅞		¼	1,920

*8 5/8	8.625	7.921	0.352	31.101	32.00	10	9.593	8 1/8	1/4	2.470
*8 5/8	8.625	7.825	0.400	35.137	36.00	10	9.593	8 1/8	1/4	3.030
*8 5/8	8.625	7.775	0.425	37.220	38.00	10	9.593	8 1/8	1/4	3.320
*8 5/8	8.625	7.651	0.487	42.327	43.00	10	9.593	8 1/8	1/4	4.040
10 3/4	10.75	10.05	0.35	38.88	40.50	8	11.75	8 1/2	1/4	1.650
10 3/4	10.75	9.95	0.40	44.22	45.50	8	11.75	8 1/2	1/4	2,100
10 3/4	10.75	9.85	0.45	49.50	51.00	8	11.75	8 1/2	1/4	2,580
10 3/4	10.75	9.76	0.495	54.22	55.50	8	11.75	8 1/2	1/4	3,000
*11 3/4	11.75	11.00	0.375	45.557	47.00	8	12.866	8 1/2	1/4	1,590
*11 3/4	11.75	10.72	0.489	58.811	60.00	8	12.866	8 1/2	1/4	2,560
13 3/8	13.375	12.715	0.33	45.97	48.00	8	14.375	9	5/16	860
13 3/8	13.375	12.615	0.38	52.73	54.50	8	14.375	9	5/16	1,230
13 3/8	13.375	12.515	0.43	59.44	61.00	8	14.375	9	5/16	1,610
13 3/8	13.375	12.415	0.48	66.10	68.00	8	14.375	9	5/16	2,000
16	16.00	15.375	0.3125	52.36	55.00	8	17.00	9	5/16	425
16	16.00	15.250	0.375	62.58	65.00	8	17.00	9	5/16	740
16	16.00	15.125	0.4375	72.72	75.00	8	17.00	9	5/16	1,130
16	16.00	15.010	0.495	81.97	84.00	8	17.00	9	5/16	1,500
18 5/8	18.625	17.855	0.385	75.00	78.00	8	19.75	9	5/16	510
18 5/8	18.625	17.755	0.435	84.51	87.50	8	19.75	9	5/16	730
18 5/8	18.625	17.655	0.485	93.96	96.50	8	19.75	9	5/16	1,000
21 1/2	21.50	20.71	0.395	89.04	92.50	8	22.625	9	5/16	360
21 1/2	21.50	20.61	0.445	100.07	103.00	8	22.625	9	5/16	510
21 1/2	21.50	20.51	0.495	111.00	114.00	8	22.625	9	5/16	700
24 1/2	24.50	23.85	0.325	83.91	88.00	8	25.625	9	5/16	130
24 1/2	24.50	23.75	0.375	96.62	100.50	8	25.625	9	5/16	200
24 1/2	24.50	23.65	0.425	109.26	113.00	8	25.625	9	5/16	300

Notes for Table 9

* Sizes for California and similar territory. These are standard at present. Dimensions and weights copied from lists now in use and "size" changed to O. D.

To ascertain setting depth with safety factor of 2 with liquids heavier than fresh water divide the tabular number of feet by specific gravity of heavier liquid, or multiply by 8½, and divide product by weight per gallon of heavier liquid.

To ascertain setting depth for any other factor than 2 multiply the tabular number of feet by 2 and divide the product by the desired factor.

Taper of threads on 10-thread pipe $\frac{3}{8}$ inch diameter per foot of length.

Taper of threads on 8-thread pipe $\frac{1}{4}$ inch diameter per foot of length.

Assuming 30 per cent greater strength to resist collapse for high-carbon seamless steel:

$4\frac{3}{4}$ inch 16-pound casing would set 7,000 feet with the factor of safety of 2.
$5\frac{3}{4}$ inch 23-pound casing would set 7,000 feet with a factor of safety of 1.85.
$6\frac{5}{8}$ inch 28-pound casing would set 6,100 feet with the factor of safety of 2.
$8\frac{5}{8}$ inch 40-pound casing would set 6,000 feet with a factor of safety of 1.82.

When joints are screwed tight the ends of casing shall be $\frac{5}{8}$ inch from center of coupling and, when in this position, the outside diameter of thread at end of coupling to be that of the nominal outside diameter of casing. Beyond the threads at the end of coupling there shall be two threads perfect at the bottom on 8-thread and three threads on 10-thread casing. A slight variation from this provision is permitted in the California sizes as follows:

Sizes	Distance End of Pipe from Center of Coupling	Number of Threads Perfect at Bottom Exposed Beyond Coupling
$4\frac{3}{4}$ inches O. D.	0.5625	2
$6\frac{5}{8}$ inches O. D.	0.6125	2
$8\frac{5}{8}$ inches O. D.	0.6125	2
$11\frac{3}{4}$ inches O. D.	0.6875	3

Extreme depth of recess in couplings, including chamfer, not to exceed $\frac{1}{8}$ inch, on 8-thread and $\frac{7}{10}$ inch on 10-thread.

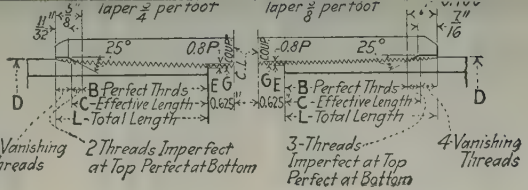


TABLE 10.—THREADS
AMERICAN PETROLEUM INSTITUTE CASING
(Dimensions in Inches)

Casing				Threads						Diameter of Casing at Root of Threads	Diameter of Casing at Top of Threads
Size	External Diameter	Diameter of Upset	Number per Inch	Taper per Foot *A*	Length of Perfect Thread *B*	Number of Perfect Thread	Effective Length *C*	Total Length *L*	Depth	*E*	*G*
4½	4.750	5.000	10	¾	2.1750	21.75	2.475	2.875	0.0800	4.772	4.932
5	5.750		10	¾	2.4250	24.25	2.725	3.125	0.0800	5.514	5.674
5½	5.750	6.000	10	¾	2.9250	29.25	3.225	3.625	0.0800	5.749	5.909
7⅝	8.125		10	¾	2.9250	29.25	3.225	3.625	0.0800	7.874	8.034
8¼	8.125	8.375	10	¾	2.9250	29.25	3.225	3.625	0.0800	8.124	8.284
10¾	10.750		8	¾	3.0000	24.00	3.250	3.625	0.1000	10.362	10.562
13⅜	13.375		8	¾	3.2500	26.00	3.500	3.875	0.1000	12.972	13.172
16	16.000		8	¾	3.2500	26.00	3.500	3.875	0.1000	15.597	15.797
18⅝	18.625		8	¾	3.2500	26.00	3.500	3.875	0.1000	18.222	18.422
21½	21.500		8	¾	3.2500	26.00	3.500	3.875	0.1000	21.097	21.297
24½	24.500		8	¾	3.2500	26.00	3.500	3.875	0.1000	24.097	24.297

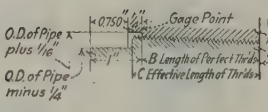


TABLE 11.—GAGES

(See Table 10 of Casing-Thread Dimensions for Lengths, etc.)

Size	Number Threads per Inch	Taper per Foot Inch	Pitch Diameter at Gage Point in Inches	Major Diameter at Gage Point in Inches
$4\frac{3}{4}$	10	$\frac{3}{8}$	4.6700	4.7366
$4\frac{3}{4}$ upset	10	$\frac{3}{8}$	4.9200	4.9866
$5\frac{3}{4}$	10	$\frac{3}{8}$	5.6700	5.7366
$5\frac{3}{4}$ upset	10	$\frac{3}{8}$	5.9200	5.9866
$6\frac{5}{8}$	10	$\frac{3}{8}$	6.5450	6.6116
$8\frac{1}{8}$	10	$\frac{3}{8}$	8.0450	8.1116
$8\frac{1}{8}$ upset	10	$\frac{3}{8}$	8.2950	8.3616
$8\frac{5}{8}$	10	$\frac{3}{8}$	8.5450	8.6116
$10\frac{3}{4}$	8	$\frac{3}{4}$	10.6500	10.7333
$11\frac{3}{4}$	8	$\frac{3}{4}$	11.6500	11.7333
$13\frac{3}{8}$	8	$\frac{3}{4}$	13.2750	13.3583
16	8	$\frac{3}{4}$	15.9000	15.9833
$18\frac{5}{8}$	8	$\frac{3}{4}$	18.5250	18.6083
$21\frac{1}{2}$	8	$\frac{3}{4}$	21.4000	21.4833
$24\frac{1}{2}$	8	$\frac{3}{4}$	24.4000	24.4833

TOLERANCES

10 Threads, $\frac{3}{8}$-inch Taper per Foot

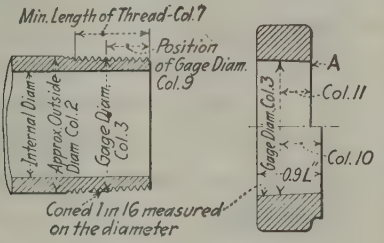
Pitch diameter	± 0.0005 inch
Lead	± 0.0003 inch in length of gage
Taper	+ 0.0005 inch in length of gage
Half included angle	± 10 minutes

8 Threads, $\frac{3}{4}$-inch Taper per Foot

Pitch diameter	± 0.0010 inch
Lead	± 0.0005 inch in length of gage
Taper	+ 0.0010 inch in length of gage
Half included angle	± 10 minutes

STANDARD PIPE THREADS[1]

British pipe ends are shown in Fig. 14 and gaged with a plain tapered ring gage, Fig. 15. The step is the tolerance. Pitch and form of thread are checked with a profile or comb gage. Inside



FIGS. 14 and 15

thread diameters of couplings and fittings are checked by gages having threads with sharp angles that will bear only on the roots of the threads. Such a gage is shown in Fig. 16. The distance from *C*

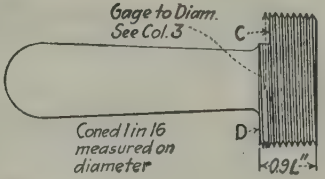


FIG. 16

to *D* is the difference between columns 10 and 11 in the table. When screwed in by hand *C* must go inside coupler and *D* must remain outside. The gage in FIG. 15 is used in the same way.

[1] By permission British Engineering Standards Committee.

TABLE 12.—BRITISH STANDARD PIPE THREADS
(Dimensions in Inches)

1	2	3	4	5	6	7	8	9	10	11
Nominal Bore of Tube	Approximate Outside Diameter of Black Tube	Gage Diameter (*See* Fig. 14.	Depth of Thread	Core Diameter, Measured at Same Distance from End of Pipe as the Gage Diameter	Number of Threads per Inch	Length of Thread		Distance of Gage Diameter from Pipe End (Class I. Taper Screw)		
						L On Pipe End Min.	In Coupler Min.	Standard	Max.	Min.
$\frac{1}{8}$	$\frac{13}{32}$	0.383	0.0230	0.337	28	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{32}$	0.18	0.13
$\frac{1}{4}$	$\frac{17}{32}$	0.518	0.0335	0.451	19	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{3}{16}$	0.22	0.16
$\frac{3}{8}$	$\frac{11}{16}$	0.656	0.0335	0.589	19	$\frac{1}{2}$	1	$\frac{1}{4}$	0.29	0.21
$\frac{1}{2}$	$\frac{21}{32}$	0.825	0.0455	0.734	14	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{1}{4}$	0.29	0.21
$\frac{5}{8}$	$\frac{13}{16}$	0.902	0.0455	0.811	14	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{1}{4}$	0.29	0.21
$\frac{3}{4}$	$1\frac{1}{16}$	1.041	0.0455	0.950	14	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{3}{8}$	0.44	0.31
$\frac{7}{8}$	$1\frac{7}{32}$	1.189	0.0455	1.098	14	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{3}{8}$	0.44	0.31
1	$1\frac{11}{32}$	1.309	0.0580	1.193	11	$\frac{7}{8}$	$1\frac{1}{4}$	$\frac{3}{8}$	0.44	0.31
$1\frac{1}{4}$	$1\frac{11}{16}$	1.650	0.0580	1.534	11	1	2	$\frac{1}{2}$	0.58	0.42
$1\frac{1}{2}$	$1\frac{23}{32}$	1.882	0.0580	1.766	11	1	2	$\frac{1}{2}$	0.58	0.42
$1\frac{3}{4}$	$2\frac{1}{32}$	2.116	0.0580	2.000	11	$1\frac{1}{4}$	$2\frac{1}{4}$	$\frac{5}{8}$	0.73	0.52
2	$2\frac{3}{8}$	2.347	0.0580	2.231	11	$1\frac{1}{8}$	$2\frac{1}{4}$	$\frac{5}{8}$	0.73	0.52
$2\frac{1}{4}$	$2\frac{5}{8}$	2.587	0.0580	2.471	11	$1\frac{1}{2}$	$2\frac{1}{2}$	$\frac{11}{16}$	0.80	0.57
$2\frac{1}{2}$	3	2.960	0.0580	2.844	11	$1\frac{1}{2}$	$2\frac{1}{2}$	$\frac{11}{16}$	0.80	0.57
$2\frac{3}{4}$	$3\frac{1}{4}$	3.210	0.0580	3.094	11	$1\frac{3}{8}$	$2\frac{1}{4}$	$\frac{11}{16}$	0.95	0.68

3	3 1/2	3.460	0.0580	3.344	11	1 3/8	2 1/4	1 13/16	0.95	0.68
3 1/2	3 3/4	3.700	0.0580	3.584	11	1 1/2	3	1 7/16	1.02	0.73
3 1/2	4	3.950	0.0580	3.834	11	1 1/2	3	1 7/8	1.02	0.73
3 1/4	4 1/4	4.200	0.0580	4.084	11	1 1/2	3	7/8	1.02	0.73
4	4 1/2	4.450	0.0580	4.334	11	1 5/8	3 1/4	1	1.17	0.83
4 1/2	5	4.950	0.0580	4.834	11	1 5/8	3 1/4	1	1.17	0.83
5	5 1/2	5.450	0.0580	5.334	11	1 3/4	3 1/2	1 1/8	1.31	0.94
5 1/2	6	5.950	0.0580	5.834	11	1 3/8	3 3/4	1 1/4	1.46	1.04
6	6 1/2	6.450	0.0580	6.334	11	2	4	1 1/8	1.60	1.15
7	7 1/2	7.450	0.0640	7.322	10	2 1/8	4 1/4	1 3/8	1.60	1.15
8	8 1/2	8.450	0.0640	8.322	10	2 1/4	4 1/4	1 1/2	1.75	1.25
9	9 1/2	9.450	0.0640	9.322	10	2 1/4	4 1/2	1 1/2	1.75	1.25
10	10 1/2	10.450	0.0640	10.322	10	2 3/8	4 3/4	1 5/8	1.90	1.35
11	11 1/2	11.450	0.0800	11.290	8	2 1/2	5	1 5/8	1.90	1.35
12	12 1/2	12.450	0.0800	12.290	8	2 1/2	5	1 5/8	1.90	1.35
13	13 1/4	13.680	0.0800	13.520	8	2 5/8	5 1/4	1 5/8	1.90	1.35
14	14 1/4	14.680	0.0800	14.520	8	2 3/4	5 1/2	1 3/4	2.04	1.46
15	15 1/4	15.680	0.0800	15.520	8	2 3/4	5 1/2	1 3/4	2.04	1.46
16	16 1/4	16.680	0.0800	16.520	8	2 7/8	5 3/4	1 7/8	2.19	1.56
17	17 1/4	17.680	0.0800	17.520	8	3	6	2	2.33	1.67
18	18 1/4	18.680	0.0800	18.520	8	3	6	2	2.33	1.67

On low-pressure copper tube work 20 threads per inch is used on sizes from 1/4 to 1 1/4 inches and 16 threads from 1 3/4 to 4 inches.

TABLE 13.—METRIC PIPE THREADS

Nominal Inside Pipe Diameter in Inches	Inside Pipe Diameter in Millimeters	External Thread Diameter in Millimeters	Internal Thread Diameter in Millimeters	Number of Threads per Inch
$\frac{1}{8}$		10	8.3	19
$\frac{1}{4}$	6.35	13	11.3	19
$\frac{3}{8}$	9.52	16.5	14.8	19
$\frac{1}{2}$	12.70	20.5	18.2	14
$\frac{5}{8}$	15.87	23	20.7	14
$\frac{3}{4}$	19.05	26.5	24.2	14
1	25.40	33	30	11
$1\frac{1}{4}$	31.75	42	39	11
$1\frac{1}{2}$	38.10	48	45	11
$1\frac{3}{4}$	44.45	52	49	11
2	50.30	59.7	56.7	11
$2\frac{1}{2}$	63.50	76	73	11
3	76.20	89	86	11
$3\frac{1}{2}$	88.90	101.5	98.5	11
4	101.60	114	111	11

NATIONAL (AMERICAN) STANDARD FIRE-HOSE COUPLING SCREW THREAD

This standard covers the threaded part of fire-hose couplings, hydrant outlets, stand-pipe connections, Siamese connections, and all other special fittings on fire lines where fittings of $2\frac{1}{2}$, 3, $3\frac{1}{2}$, and $4\frac{1}{2}$ in. nominal diameter are used. It should be noted also

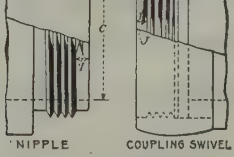


FIG. 17.—Standard Hose Couplings

that they determine the size of the finished product and not of the threading tools. The Standard Fire-Hose Coupling Screw Thread is the American (National) Standard form.

TABLE 14.—CHARACTERISTICS OF THE NATIONAL STANDARD FIRE-HOSE COUPLING SCREW THREAD
(All Dimensions in Inches)

C Nominal inside diameter of hose coupling	$2\frac{1}{2}$	3	$3\frac{1}{2}$	$4\frac{1}{2}$
N Number of threads per inch	$7\frac{1}{2}$	6	6	4
L Total length of threaded part of coupling and hydrant nipple, external thread	1	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$
I Distance from face of nipple to start of second turn	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{7}{16}$
H Depth of coupling swivel to washer seat	$\frac{15}{16}$	$1\frac{1}{16}$	$1\frac{1}{16}$	$1\frac{3}{16}$
J Distance from face of coupling swivel to start of second turn	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{8}$
T Depth of thread of coupling swivel	$\frac{11}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{15}{16}$

TABLE 15.—LIMITING DIMENSIONS FOR THREADS OF COUPLING SWIVELS AND HYDRANT CAPS (INTERNAL[1])
(All Dimensions in Inches)

Nominal Size	No. of Threads per Inch	Min. Major Diameter[2]	Pitch Diameter		Minor Diameter	
			Max.	Min.	Max.	Min.
2.500	7.5	3.0836	3.0130	2.9970	2.9424	2.9104
3.000	6.0	3.6389	3.5486	3.5306	3.4583	3.4223
3.500	6.0	4.2639	4.1736	4.1556	4.0833	4.0473
4.500	4.0	5.7859	5.6485	5.6235	5.5111	5.4611

TABLE 16.—LIMITING DIMENSIONS OF THREADS OF COUPLING AND HYDRANT NIPPLES (EXTERNAL[1])
(Dimensions in Inches)

Nominal Size	No. of Threads per Inch	Major Diameter		Pitch Diameter		Max. Minor Diameter[3]
		Max.	Min.	Max.	Min.	
2.500	7.5	3.0686	3.0366	2.9820	2.9660	2.8954
3.000	6.0	3.6239	3.5879	3.5156	3.4976	3.4073
3.500	6.0	4.2439	4.2079	4.1356	4.1176	4.0273
4.500	4.0	5.7609	5.7109	5.5985	5.5735	5.4361

[1] The largest nipple is purposely made smaller in diameter than the smallest coupling in order to insure a fit loose enough so that these threads can be assembled quickly regardless of the presence of dirt, burrs, bruises, etc.

[2] These dimensions correspond to the basic flat ($\frac{1}{4}p$). The profile at the major diameter of the coupling, produced by a worn tool, must not fall below the basic outline, but a new tool may be made with a flat at the point as small as $\frac{1}{24}p$ (p = pitch of thread).

[3] These dimensions are figured to the intersection of the worn-tool arc with a center line through crest and root. New tools may be made to give a minimum minor diameter of the nipple as small as that corresponding to a flat of $\frac{1}{24}p$.

TABLE 17.—LIMITING DIMENSIONS OF FIELD INSPECTION PLUG SCREW THREAD GAGES FOR COUPLING SWIVELS AND HYDRANT CAPS (INTERNAL)
(Dimensions in Inches)

Nominal Size	No. of Threads per Inch	"Go" or Minimum Gage				"Not Go" or Maximum Gage			
		Major Diam.		Pitch Diam.		Major Diam.		Pitch Diam.	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2.500	7.5	3.0846	3.0836	2.9980	2.9970	3.0836	3.0826	3.0130	3.0120
3.000	6.0	3.6399	3.6389	3.5316	3.5306	3.6389	3.6379	3.5486	3.5476
3.500	6.0	4.2649	4.2639	4.1566	4.1556	4.2639	4.2629	4.1736	4.1726
4.500	4.0	5.7869	5.7859	5.6245	5.6235	5.7859	5.7849	5.6485	5.6475

NOTES.—(*a*) The minor diameters of plug thread gages are undercut below the nominal minor diameter to give clearance for grinding or lapping.
(*b*) The allowance variation in lead between any two threads not farther apart than the length of engagement is ± 0.0005 inch.
(*c*) The allowable variation in one-half angle of thread is ± 10 minutes.
(*d*) The diameters of the "not go" field inspection plain plug gages are the same as those given for the maximum minor diameter of couplings given in Table 15.

GAGING STANDARD FIRE-HOSE COUPLING SCREW THREADS

National (American) Standard Fire-Hose Coupling Screw Thread will be inspected in the field by plug and ring gages made within the limiting dimensions given in Tables 15 and 16. These will be in the hands of the representative of the purchaser, who will in most cases be the Fire Chief or the Superintendent of Water Works, or both.

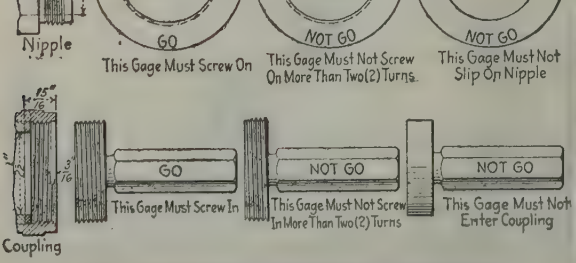


FIG. 18.—Gages for Standard Hose Couplings

The manufacturers' gages should, therefore, be made an appreciable amount within the limiting dimensions of these field inspection gages, by whatever amount may be desired, so as to allow for gage wear and also to avoid, as far as possible, disagreements which might otherwise arise due to slight differences in the dimensions of the gages.

TABLE 18.—LIMITING DIMENSIONS OF FIELD INSPECTION RING SCREW THREAD GAGES FOR COUPLING AND HYDRANT NIPPLES (EXTERNAL)

(Dimensions in Inches)

Nominal Size	No. of Threads per Inch	"Go" or Maximum Gage				"Not Go" or Minimum Gage			
		Pitch Diam.		Minor Diam.		Pitch Diam.		Minor Diam.	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2.500	7.5	2.9820	2.9810	2.9104	2.9094	2.9670	2.9660	2.9114	2.9104
3.000	6.0	3.5156	3.5146	3.4223	3.4213	3.4986	3.4976	3.4233	3.4223
3.500	6.0	4.1356	4.1346	4.0473	4.0463	4.1186	4.1176	4.0483	4.0473
4.500	4.0	5.5985	5.5975	5.4611	5.4601	5.5745	5.5735	5.4621	5.4611

NOTES.—(*a*) The major diameters of the ring thread gages are undercut beyond the nominal major diameters to give clearance for grinding or lapping.

(*b*) The allowable variation in lead between any two threads not farther apart than the length of engagement is ± 0.0005 inch.

(*c*) The allowable variation in one-half angle of thread is ± 10 minutes.

(*d*) The diameters of the "not go" field inspection plain ring gages are the same as those given for the minimum major diameter of nipples given in Table 16.

TWIST-DRILLS

THE twist-drill is perhaps one of the most efficient tools in use as, although one half is cut away in the flutes, it has a very large cutting surface in proportion to its cross-sectional area. This is made possible by the fact that the work helps to support the drill and the feed pressure on the drill tends to force the point into a cone-shaped hole which centers it.

In addition to the radial relief or backing-off behind the cutting edge, twist-drills have longitudinal clearance by decreasing the diameter from the point toward the shank, varying from .00025 to .0015 per inch of length. This prevents binding and is essential in accurate drilling.

The shape of the groove affects the power and the shape of the chip and experiments by the Cleveland Twist Drill Company are interesting. The groove in Fig. 1 does not give a good cutting edge

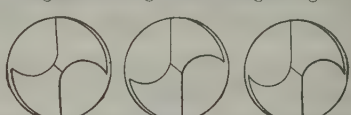


FIG. 1 FIG. 2 FIG. 3

Grooves of Twist Drills

especially near the center, as it does not allow a full curl to the chip. Fig. 2 is a very free cutting-groove, the chips curl up to the full size of the groove and this reduces the power required to bend the chips. Fig. 3 is an even better form as it rolls a chip with each turn conical so that one lays inside the other and makes a much shorter chip from the same depth of hole.

The angle of spirals varies from 18 to 35 degrees. In theory the finer the pitch or the greater the angle, the easier it should be to cut and curl the chip. But this gives a weak cutting edge and reduces the ability to carry off the heat, and it does not clear itself of chips so well. After a long series of tests the same firm adopted 27½ degrees for the spiral. This angle makes the spiral groove of all drills start at the point with a pitch equal to six diameters of the blank, the increase in twist being a constant function of the angular movement of rotation of the drill blank. This angle is based on holes from one to three diameters deep. For deeper holes a smaller angle might be advisable and greater angle for holes of less depth. There is practically no difference in torsional stress with the angle between 25 and 30 degrees.

SHARPENING DRILLS

Drills should be sharpened so as to cut the right size and with as little power as possible. To cut the right size both lips must be the

same length and the same angle. A gage as shown in Fig. 4 will help both to get the angle and to grind them central. This gives the usual lip edge of 59 degrees. Fig. 5 shows how you can see if both lips are ground alike, but does not give the angle. Fig. 6 is a suggestion by Professor Sweet of relieving the drill back of the cutting edge, making it similar to a flat drill in this respect.

For drilling brass or for any thin stock where the drill goes clear through, it is best to grind the cutting edge parallel with the axis of the drill. This does away with the tendency to draw into the work. Fig. 7 shows how this is done.

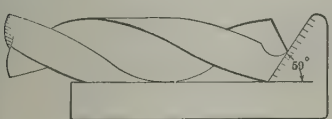


FIG. 4

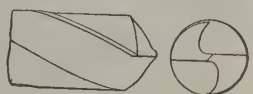


FIG. 7

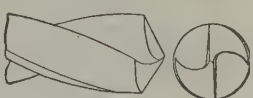


FIG. 8

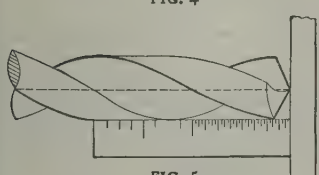


FIG. 5

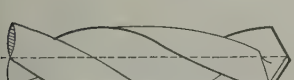


FIG. 6

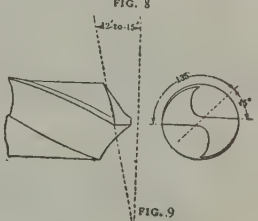


FIG. 9

Grinding Twist Drills

It is sometimes necessary to thin the point of the drill to get best results. This requires care in grinding but can be done as shown in Fig. 8.

The best all-around clearance angle is 12 degrees, though for softer metals 15 degrees can be used. The 12 degrees is the angle at the cutting edge, but this should increase back of the cutting edge so that the line across the web should be 45 degrees, with the cutting edges. This is important, as it not only saves power but prevents splitting in hard service. The point of the drill should look like Fig. 7 or Fig. 8. Fig. 9 shows the clearance angle and the right angles for the drill point.

Speed of Drills

Learn to run drills at their proper speed to secure the most work with fewest grindings and breakages. It is good practice to use a speed that will give 30 feet a minute cutting speed for steel, 35 feet

for cast iron and 60 feet for brass. This means that the cutting edge must run fast enough to make these speeds. For drilling steel with a $\frac{1}{16}$-inch drill this means 1834 revolutions a minute, while for brass it would be 3668 revolutions. The table gives the speeds without any figuring for all drills up to 3 inches. These speeds require plenty of lubricant. This is for carbon steel drills.

These speeds can be exceeded in many cases even with carbon drills, and can be doubled with high speed drills, in fact from 75 to 150 feet is not uncommon with 200 feet a possibility under good conditions. The feeds in the table below can also be doubled in many cases.

TABLE OF DRILL FEEDS FOR CARBON DRILLS

Diam. of Drill	Inches of Feed per Minute at Cutting Speed of								
	30 Feet–Steel			35 Feet–Iron			60 Feet–Brass		
	Rev. per Minute	Feed .004-.007		Rev. per Minute	.004-.007		Rev. per Minute	.004-.007 per Revolution	
$\frac{1}{16}$	1834	7.33	12.83	2140	8.56	14.97	3668	14.66	25.76
$\frac{1}{8}$	917	3.66	6.41	1070	4.28	7.49	1834	7.33	12.83
$\frac{3}{16}$	611	2.44	4.27	713	2.85	4.99	1222	4.88	8.58
$\frac{1}{4}$	458	1.83	3.20	535	2.14	3.74	917	3.66	6.44
		Feed .007	.015		.007	.015		.007	.015
$\frac{5}{16}$	367	2.57	5.5	428	3	6.42	733	5.14	11
$\frac{3}{8}$	306	2.14	4.6	357	2.5	5.35	611	4.28	9.2
$\frac{7}{16}$	262	1.83	3.9	306	2.14	4.58	524	3.66	7.8
$\frac{1}{2}$	229	1.60	3.43	268	1.87	4.	459	3.20	6.86
$\frac{9}{16}$	184	1.28	2.75	214	1.50	3.21	367	2.57	5.5
$\frac{3}{4}$	153	1.07	2.3	178	1.25	2.67	306	2.14	4.6
$\frac{7}{8}$	131	.91	1.95	153	1.07	2.29	262	1.88	3.93
1	115	.80	1.71	134	.93	2	229	1.60	3.43
$1\frac{1}{8}$	102	.71	1.53	119	.83	1.79	204	1.43	3.06
$1\frac{1}{4}$	91.8	.64	1.37	107	.75	1.61	183	1.28	2.75
$1\frac{3}{8}$	83.3	.58	1.25	97.2	.68	1.45	167	1.17	2.51
$1\frac{1}{2}$	76.3	.53	1.15	89.2	.62	1.38	153	1.07	2.3
$1\frac{5}{8}$	70.5	.49	1.05	82.2	.57	1.23	141	.99	2.11
$1\frac{3}{4}$	65.5	.45	.97	76.4	.53	1.15	131	.94	1.96
$1\frac{7}{8}$	61.1	.42	.92	71.3	.50	1.07	122	.85	1.81
2	57.3	.40	.85	66.9	.46	1.	115	.80	1.73
$2\frac{1}{4}$	51	.36	.71	59.4	.41	.89	102	.71	1.53
$2\frac{1}{2}$	45.8	.32	.68	53.5	.37	.80	91.7	.64	1.37
$2\frac{3}{4}$	41.7	.29	.62	48.6	.34	.73	83.4	.58	1.21
3	38.2	.27	.57	44.6	.31	.67	76.4	.53	1.15

FEED OF DRILLS

The feed of drills is usually given in parts of an inch per revolution, 0.004 to 0.007 inch for drills of $\frac{1}{4}$ inch and smaller and 0.007 to 0.015 inch for larger drills being recommended. This has been

worked out into the table for the standard speeds to show inches of feed per minute for the three speeds given, which is more convenient. This is not an iron-clad rule but should be used with judgment. For high-speed steel drills these figures can be just about doubled.

DATA FOR DRILLING CAST IRON AT FEED OF 1″ PER MIN.

Size of Drill	Feed per Rev.	Thrust in Lbs.	H.P. for 1 Inch Feed per Min.	Size of Drill	Feed per Rev.	Thrust in Lbs.	H.P. for 1 Inch Feed per Min.
1	.02	1300	.0035		.06	8000	.02
	.04	2600	.0063	2½	.02	3200	.008
	.06	3900	.010		.04	6500	.016
1½	.02	2000	.005		.06	9700	.024
	.04	3900	.010	3	.02	3750	.009
	.06	5800	.015		.04	7700	.019
2	.02	2500	.006		.06	11500	.029
	.04	5300	.013				

For carbon steel the values run from 1½ to 3 times these for cast iron, increasing with the feed per revolution.

One inch flat twisted drills have been run from 313 to 575 r. p. m., with feeds of 11.27 and 28.1 inches per minute and required from 5.22 to 11.60 actual horse power.

TORQUE REQUIRED TO DRILL CAST IRON

Diam. of Drill	Feed in Inch per Rev.	Pounds Torque at 1 foot Radius	H.P. per Rev.	Diam of Drill	Feed in Inch per Rev.	Pounds Torque at 1 foot Radius	H.P. per Rev.
1	.02	50	.009		.06	390	.072
	.04	80	.014	2½	.02	200	.038
	.06	120	.023		.04	400	.076
1½	.02	75	.014		.06	600	.114
	.04	150	.028	3	.02	280	.053
	.06	225	.042		.04	575	.109
2	.02	125	.023		.06	870	.167
	.04	255	.048				

DRILL TROUBLES

Twist-drills will stand more strain in proportion to their size and weight than almost any other tool, and when a good drill gives trouble it is pretty safe to say some of the conditions are wrong.

If it chips on the edge, the lip clearance is too great and fails to support the cutting edge or the feed is too heavy. Ease off on the feed first and then watch the grinding.

If it splits in the web it is either ground wrong, *i.e.*, does not have the center lip at the angle of 45 degrees or the feed is altogether too heavy.

If the outer corner wears, it shows that the speed is too great. This is particularly noticeable on cast iron.

Drill Pointers

In most cases it is better to use high speeds almost to the point where the drill corners commence to wear with a light feed than to use slower speed and heavy feed.

This is specially true of drilling in automatic machines where the holes are not more than twice as deep as the diameter where drills are flooded with lard oil. With deeper holes the chips are harder to get rid of and it is better to use slower speeds and heavier feeds as the drilled hole gets deeper. Speeds of 10,000 r. p. m. for drills $\frac{1}{16}$ in. and smaller are not uncommon.

Watch the drill chip and try to grind so that it will come out in a small compact roll. It is better to have this continuous clear to bottom of hole if possible.

In drilling brass use a heavier feed especially on automatic machines, as it helps to work out the chips. If you lubricate at all, flood the work. Twist-drills ground as for steel often catch and "hog in" on brass, especially at the bottom of the hole, where it breaks through. To avoid this, grind the lead or rake from the cutting edge.

In drilling hard material use turpentine as a lubricant.

Drills feed easier by thinning the extreme point if this is carefully done. This is important in hand feeding.

High-speed drills work best when warm. Lubricant should be heated to 150 degrees Fahr. when starting drills to work; they will soon maintain the proper temperature.

Special Drills and Their Uses

Ratchet-drills have a square taper shank, are used in hand-ratchet braces and in air-driven drills. Used in bridge building, structural and repair work.

The shell drill, Fig. 10, is used after a two-groove drill in chucking out cored holes or for enlarging holes that have been made with a two-groove drill. It has a taper hole and a number of sizes can be used on the same arbor.

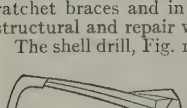


Fig. 10.—Shell Drill

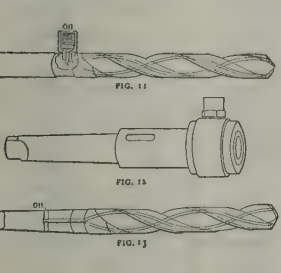
Wire drills and jobbers or machinists drills both have round shanks and only differ in size. Wire drills are made to a twist-drill gage and the others to a jobbers or fractional gage.

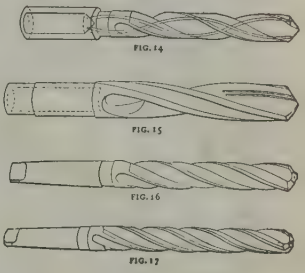
Blacksmith drills all have a $\frac{1}{2}$-inch shank $2\frac{1}{2}$ inches long, so as to all fit the same holder. There is a flat on the shank for set-screw.

The straightway or Farmers drill has the same clearance as a twist-drill but the flutes are straight. It is used mostly in drilling brass and soft metals or in drilling cross holes or castings where blow holes may be found, as it is less likely to run than the twist-drill.

Oil drills have the advantage of the cutting edge being kept cool and of the chips being forced back through the grooves which reduces friction to a minimum. They are used for all kinds of drilling, mostly deep hole work. In cast-iron drilling air is sometimes used to blow out the chips and keep the drill cool. They are generally used in a screw or chucking machine or a lathe fitted for this work. Where the drill is held stationary and the work revolves, the oil is pumped to the connection and flows through the holes in the drill as in Fig. 11.

Where the drill revolves as in a drill press, the oil is pumped into a collar which remains stationary while the drill socket revolves, as in Fig. 12. An oil groove around the socket and holes through to the drill connects with the holes in the drill itself. Other types are shown in Figs. 13 and 14. The latter is used mostly in screw or chucking machine turrets where the oil is pumped into the center of the turret and into the large hole in the shank of the drill.





FIGS. 11 to 17.—Several Kinds of Drills

The hollow drill shown in Fig. 15 is used for deep drilling or long holes and is used in a lathe or some similar machine fitted for the purpose. It has a hole lengthwise through the shank connecting with the grooves of the drill. The shank can be threaded and fitted to a metal tube of such length as desired. The outside of the drill has a groove the whole length of the body. The lubricant is conveyed to the point of the drill on the outside through these grooves, while the hollow tube admits of the passage of oil and chips from the point. In using this drill the hole is first started with a short drill the size of the hole desired and drilled to a depth equal to the length of the body of the hollow drill to be used. The body of the hollow drill acts as a packing, compelling the oil to follow the grooves and the chips to flow out through the hollow shank.

Three and four groove drills are used for chucking out cored holes or enlarged holes that are first drilled with a two-groove drill. They are much better than a two-groove drill for use in cored holes or to follow another drill. The ends of the drills, Figs. 16 and 17, indicate that they are not made to drill from solid stock but for enlarging a hole already made.

The following tables give standard drill sizes in various ways, each being very convenient for certain classes of work:

DECIMAL EQUIVALENTS OF NOMINAL SIZES OF DRILLS

Inch	M.M.	Wire Gage	Decimals of an Inch
		80	.0135
		79	.0145
1/64			.015625
	.4		.01574
		78	.016
		77	.018
	.5		.01968
		76	.020
		75	.021
		74	.0225
	.6		.02362
		73	.024
		72	.025
		71	.026
	.7		.02756
		70	.028
		69	.02925
		68	.031
1/32			.03125
	.8		.031496
		67	.032
		66	.033
		65	.035
	.9		.03543
		64	.036
		63	.037
		62	.038
		61	.039
	1		.03937
		60	.04
		59	.041
		58	.042
		57	.043
	1.1		.043307
		56	.0465
3/64			.046875
		1.2	.047244
		1.3	.051181
			.052
			.055
		1.4	.055118
		1.5	.05905
			.0595
1/16			.0625
		1.6	.06299
			.0635
		1.7	.066929
			.067
			.07
		1.8	.070866
			.073
		1.9	.0748
			.076
5/64			.078125
			.0785
		2	.07874
			.081
			.082
		2.1	.082677
			.086
		2.2	.0866 14
			.089
		2.3	.09055
			.0935
3/32			.09375
		2.4	.09448
			.096
			.098
		2.5	.098425
			.0995
			.1015
		2.6	.102362
			.104
		2.7	.1063
			.1065
7/64			.109375
			.11
		2.8	.11024
			.111
			.113
		2.9	.11417
			.116
		3	.11811
			.12
		3.1	.12205
1/8			.125
		3.2	.12598
			.1285
		3.3	.12992
		3.4	.13386
			.136
		3.5	.1378
			.1405
9/64			.140625
		3.6	.14173
			.144
		3.7	.14567
			.147
			.1495
		3.8	.14961
			.152
		3.9	.15344
			.154
5/32			.15625
			.157
	4		.15748
			.159
			.161

DECIMAL EQUIVALENTS OF NOMINAL SIZES OF DRILLS, *Continued*

Inch	M.M.	Wire Gage	Decimals of an Inch	Inch	M.M.	Letter Sizes	Decimals of an Inch	Inch	M.M.	Letter Sizes	Decimals of an Inch
	4.1		.16142			A	.234			P	.323
	4.2		.16536	$\frac{15}{64}$			.234375	$\frac{21}{64}$			.328125
		19	.166		6		.23622			Q	.332
	4.3		.16929			B	.238		8.5		.33465
		18	.1695		6.1		.24015		8.6		.33859
$\frac{11}{64}$			.171875			C	.242			R	.339
		17	.173		6.2		.2441	$\frac{11}{32}$			.34375
	4.4		.17323			D	.246		8.8		.34646
		16	.177		6.3		.24803			S	.348
	4.5		.17717	$\frac{1}{4}$		E	.25		9		.35433
		15	.18		6.4		.25197			T	.358
	4.6		.1811		6.5		.25591	$\frac{23}{64}$			.359375
		14	.182			F	.257		9.2		.36221
		13	.185		6.6		.25984			U	.368
	4.7		.18504			G	.261		9.5		.37402
$\frac{3}{16}$			.1875		6.7		.26377	$\frac{3}{8}$			.375
	4.8		.18898	$\frac{17}{64}$			.265625			V	.377
		12	.189			H	.266		9.6		.37796
		11	.191		6.8		.26772		9.8		.38583
	4.9		.19291		6.9		.27165			W	.386
		10	.1935			I	.272	$\frac{25}{64}$			.390625
		9	.196		7		.27559		10		.3937
	5		.19685			J	.277			X	.397
		8	.199		7.1		.27952			Y	.404
	5.1		.20079			K	.281	$\frac{13}{32}$			.40625
		7	.201	$\frac{9}{32}$			.28125			Z	.413
$\frac{13}{64}$			.203125		7.2		.28347		10.5		.4134
		6	.204		7.3		.2874	$\frac{27}{64}$			.421875
	5.2		.20473			L	.29		11		.43307
		5	.2055		7.4		.29133	$\frac{7}{16}$			.4375
	5.3		.20866			M	.295		11.5		.45276
		4	.209		7.5		.29528	$\frac{29}{64}$			.453125
	5.4		.2126	$\frac{19}{64}$			.296875	$\frac{15}{32}$			.46875
		3	.213		7.6		.29922		12		.47244
	5.5		.21654			N	.302	$\frac{31}{64}$			.484375
$\frac{7}{32}$			.21875		7.7		.30314		12.5		.4921
	5.6		.22047		7.8		.30709	$\frac{1}{2}$			.5
		2	.221		7.9		.31102				
	5.7		.22441	$\frac{5}{16}$			.3125				
		1	.228		8.		.31496				
	5.8		.22835			O	.316				
	5.9		.23228		8.2		.32284				

DECIMAL EQUIVALENTS OF NOMINAL SIZES OF DRILLS, *Continued*

Inch	M.M.	Decimals of an Inch	Inch	M.M.	Decimals of an Inch	Inch	M.M.	Decimals of an Inch
	13	.51181	$\frac{43}{64}$		.671875	$\frac{27}{32}$		.84375
$\frac{33}{64}$		.515625	$\frac{11}{16}$		.6875		21.5	.84646
$\frac{17}{32}$		.53125		17.5	.689	$\frac{55}{64}$		.859375
	13.5	.5315	$\frac{45}{64}$		.703125		22	.86614
$\frac{35}{64}$		.546875		18	.70866	$\frac{7}{8}$		.875
	14	.55118	$\frac{23}{32}$		.71875		22.5	.88583
$\frac{9}{16}$		.5625		18.5	.72835	$\frac{57}{64}$		.890625
	14.5	.57087	$\frac{47}{64}$		.734375		23	.90551
$\frac{37}{64}$		.578125		19	.74803	$\frac{29}{32}$		.90625
	15	.59055	$\frac{3}{4}$		.75	$\frac{59}{64}$		.921875
$\frac{19}{32}$		.59375	$\frac{49}{64}$		.765625		23.5	.9252
$\frac{39}{64}$		.609375		19.5	.76772	$\frac{15}{16}$		.9375
	15.5	.61024	$\frac{25}{32}$		.78125		24	.94488
$\frac{5}{8}$		.625		20	.7874	$\frac{61}{64}$		.953125
	16	.62992	$\frac{51}{64}$		.796875		24.5	.9646
$\frac{41}{64}$		.640625		20.5	.8071	$\frac{31}{32}$		.96875
	16.5	.6496	$\frac{13}{16}$		.8125		25	.98425
$\frac{21}{32}$		.65625		21	.82677	$\frac{63}{64}$		.984375
	17	.66929	$\frac{53}{64}$		.828125	1		1.

LETTER SIZES OF DRILLS

Diameter Inches	Decimals of 1 Inch	Diameter Inches	Decimals of 1 Inch
A $\frac{15}{64}$	.234	N	.302
B	.238	O $\frac{5}{16}$	.316
C	.242	P $\frac{21}{64}$	.323
D	.246	Q	.332
E $\frac{1}{4}$	.250	R $\frac{11}{32}$	.339
F	.257	S	.348
G	.261	T $\frac{23}{64}$	.358
H $\frac{17}{64}$	.266	U	.368
I	.272	V $\frac{3}{8}$	.377
J	.277	W $\frac{25}{64}$	.386
K $\frac{9}{32}$	.281	X	.397
L	.290	Y $\frac{13}{32}$	.404
M $\frac{19}{64}$	.295	Z	.413

DECIMAL EQUIVALENTS OF DRILL SIZES FROM 1/2" TO No. 80

Size	Decimal Equivalent	Size	Decimal Equivalent	Size	Decimal Equivalent
1/2	0.500	3	0.213	3/32	0.0937
31/64	0.4843	4	0.209	42	0.0935
15/32	0.4687	5	0.2055	43	0.089
29/64	0.4531	6	0.204	44	0.086
7/16	0.4375	13/64	0.2031	45	0.082
27/64	0.4218	7	0.201	46	0.081
Z	0.413	8	0.199	47	0.0785
13/32	0.4062	9	0.196	5/64	0.0781
Y	0.404	10	0.1935	48	0.076
X	0.397	11	0.191	49	0.073
25/64	0.3906	12	0.189	50	0.070
W	0.386	3/16	0.1875	51	0.067
V	0.377	13	0.185	52	0.0635
3/8	0.375	14	0.182	1/16	0.0625
U	0.368	15	0.180	53	0.0595
23/64	0.3593	16	0.177	54	0.055
T	0.358	17	0.173	55	0.052
S	0.348	11/64	0.1718	3/64	0.0468
11/32	0.3437	18	0.1695	56	0.0465
R	0.339	19	0.166	57	0.043
Q	0.332	20	0.161	58	0.042
21/64	0.3281	21	0.159	59	0.041
P	0.323	22	0.157	60	0.040
O	0.316	5/32	0.1562	61	0.039
5/16	0.3125	23	0.154	62	0.038
N	0.302	24	0.152	63	0.037
19/64	0.2968	25	0.1495	64	0.036
M	0.295	26	0.147	65	0.035
L	0.290	27	0.144	66	0.033
9/32	0.2812	9/64	0.1406	1/32	0.0312
K	0.281	28	0.1405	67	0.032
J	0.277	29	0.136	68	0.031
I	0.272	30	0.1285	69	0.029
H	0.266	1/8	0.125	70	0.028
17/64	0.2656	31	0.120	71	0.026
G	0.261	32	0.116	72	0.025
F	0.257	33	0.113	73	0.024
E-1/4	0.250	34	0.111	74	0.0225
D	0.246	35	0.110	75	0.021
C	0.242	7/64	0.1093	76	0.020
B	0.238	36	0.1065	77	0.018
15/64	0.2343	37	0.104	1/64	0.0156
A	0.234	38	0.1015	78	0.016
1	0.228	39	0.0995	79	0.0145
2	0.221	40	0.098	80	0.0135
7/32	0.2187	41	0.096		

Basic Thread Dimensions and Tap Drill Sizes
American Machine Screw

Nominal Size	Outside Diameter in Inches	Pitch Diameter in Inches	Root Diameter in Inches	Commercial Tap Drill to Produce Approx. 75% Full Thread	Decimal Equivalent of Tap Drill
0–80–F	0.0600	0.0519	0.0438	3/64	0.0469
1–56	0.0730	0.0614	0.0498	54	0.0550
64–C	0.0730	0.0629	0.0527	53	0.0595
72–F	0.0730	0.0640	0.0550	53	0.0595
2–56–C	0.0860	0.0744	0.0628	50	0.0700
64–F	0.0860	0.0759	0.0657	50	0.0700
3–48–C	0.0990	0.0855	0.0719	47	0.0785
56–F	0.0990	0.0874	0.0758	45	0.0820
4–32	0.1120	0.0917	0.0714	45	0.0820
36	0.1120	0.0940	0.0759	44	0.0860
40–C	0.1120	0.0958	0.0795	43	0.0890
48–F	0.1120	0.0985	0.0849	42	0.0935
5–36	0.1250	0.1078	0.0889	40	0.0980
40–C	0.1250	0.1088	0.0925	38	0.1015
44–F	0.1250	0.1102	0.0955	37	0.1040
6–32–C	0.1380	0.1177	0.0974	36	0.1065
36	0.1380	0.1200	0.1019	34	0.1110
40–F	0.1380	0.1218	0.1055	33	0.1130
7–30	0.1510	0.1294	0.1077	31	0.1200
32	0.1510	0.1307	0.1104	31	0.1200
36	0.1510	0.1330	0.1149	1/8	0.1250
8–30	0.1640	0.1423	0.1207	30	0.1285
32–C	0.1640	0.1437	0.1234	29	0.1360
36–F	0.1640	0.1460	0.1279	29	0.1360
40	0.1640	0.1478	0.1315	28	0.1405
9–24	0.1770	0.1499	0.1229	29	0.1360
30	0.1770	0.1553	0.1337	27	0.1440
32	0.1770	0.1567	0.1364	26	0.1470
10–24–C	0.1900	0.1629	0.1359	25	0.1495
28	0.1900	0.1668	0.1436	23	0.1540
30	0.1900	0.1684	0.1467	22	0.1570
32–F	0.1900	0.1697	0.1494	21	0.1590
12–24–C	0.2160	0.1889	0.1619	16	0.1770
28–F	0.2160	0.1928	0.1696	14	0.1820
32	0.2160	0.1957	0.1754	13	0.1850

C = coarse-thread standard. F = fine-thread standard.

Basic Thread Dimensions and Tap Drill Sizes
American Coarse Thread

Nominal Size	Outside Diameter in Inches	Pitch Diameter in Inches	Root Diameter in Inches	Commercial Tap Drill to Produce Approx. 75% Full Thread	Decimal Equivalent of Tap Drill
1/16–64	0.0625	0.0524	0.0422	3/64	0.0469
72	0.0625	0.0535	0.0445	3/64	0.0469
5/64–60	0.0781	0.0673	0.0563	1/16	0.0625
72	0.0781	0.0691	0.0601	52	0.0635
3/32–48	0.0938	0.0803	0.0667	49	0.0730
50	0.0938	0.0808	0.0678	49	0.0730
7/64–48	0.1094	0.0959	0.0823	43	0.0890
1/8–32	0.1250	0.1047	0.0844	3/32	0.0937
40	0.1250	0.1088	0.0925	38	0.1015

BASIC THREAD DIMENSIONS AND TAP DRILL SIZES, *Continued*

AMERICAN COARSE THREAD

Nominal Size	Outside Diameter in Inches	Pitch Diameter in Inches	Root Diameter in Inches	Commercial Tap Drill to Produce Approx. 75% Full Thread	Decimal Equivalent to Tap Drill
5/64–40	0.1406	0.1244	0.1081	32	0.1160
5/32–32	0.1563	0.1360	0.1157	1/8	0.1250
36	0.1563	0.1382	0.1202	30	0.1285
11/64–32	0.1719	0.1505	0.1313	9/64	0.1406
3/16–24	0.1875	0.1604	0.1334	26	0.1470
32	0.1875	0.1672	0.1469	22	0.1570
13/64–24	0.2031	0.1760	0.1490	20	0.1610
7/32–24	0.2188	0.1919	0.1646	16	0.1770
32	0.2188	0.1985	0.1782	12	0.1890
15/64–24	0.2344	0.2073	0.1806	10	0.1935
1/4–20	0.2500	0.2175	0.1850	7	0.2010
24	0.2500	0.2229	0.1959	4	0.2090
27	0.2500	0.2260	0.2019	3	0.2130
28	0.2500	0.2268	0.2036	3	0.2130
32	0.2500	0.2297	0.2094	7/32	0.2187
5/16–18	0.3125	0.2764	0.2403	F	0.2570
20	0.3125	0.2800	0.2476	17/64	0.2656
24	0.3125	0.2854	0.2584	I	0.2720
27	0.3125	0.2884	0.2644	J	0.2770
32	0.3125	0.2922	0.2719	9/32	0.2812
3/8–16	0.3750	0.3344	0.2938	19/64	0.3125
20	0.3750	0.3425	0.3100	21/64	0.3281
24	0.3750	0.3479	0.3209	Q	0.3320
27	0.3750	0.3509	0.3269	R	0.3390
7/16–14	0.4375	0.3911	0.3447	U	0.3680
20	0.4375	0.4050	0.3726	11/32	0.3906
24	0.4375	0.4104	0.3834	X	0.3970
27	0.4375	0.4134	0.3894	Y	0.4040
1/2–12	0.5000	0.4459	0.3918	27/64	0.4219
13	0.5000	0.4501	0.4001	27/64	0.4219
20	0.5000	0.4675	0.4351	29/64	0.4531
24	0.5000	0.4729	0.4459	29/64	0.4531
27	0.5000	0.4759	0.4519	29/64	0.4687
9/16–12	0.5625	0.5084	0.4542	31/64	0.4844
18	0.5625	0.5264	0.4903	33/64	0.5156
27	0.5625	0.5384	0.5144	17/32	0.5312
5/8–11	0.6250	0.5666	0.5069	17/32	0.5312
12	0.6250	0.5709	0.5168	35/64	0.5469
18	0.6250	0.5889	0.5528	37/64	0.5781
27	0.6250	0.6009	0.5769	37/64	0.5937
11/16–11	0.6875	0.6285	0.5694	37/64	0.5937
16	0.6875	0.6469	0.6063	39/64	0.6250
3/4–10	0.7500	0.6850	0.6201	41/64	0.6562
12	0.7500	0.6959	0.6418	43/64	0.6719
16	0.7500	0.7094	0.6688	43/64	0.6875
27	0.7500	0.7259	0.7019	43/64	0.7187
13/16–10	0.8125	0.7476	0.6826	43/64	0.7187
7/8– 9	0.8750	0.8029	0.7307	49/64	0.7656
12	0.8750	0.8209	0.7668	51/64	0.7969
14	0.8750	0.8286	0.7822	51/64	0.8125
18	0.8750	0.8389	0.8028	53/64	0.8281
27	0.8750	0.8509	0.8269	53/64	0.8437

TAP DRILLS

A very simple rule, which is good enough in many cases, is:
Subtract the pitch of one thread from the diameter of the tap.

A $\frac{3}{8}$-inch tap 16-thread would be $\frac{3}{8}$ minus $\frac{1}{16} = \frac{5}{16}$ drill; a $\frac{3}{4}$-inch tap, 10-thread, would be $\frac{3}{4}$ minus $\frac{1}{10} = \frac{7.5}{10.0} - \frac{1.0}{10.0}$ or $0.75 - 0.10 = \frac{6.5}{10.0}$ or 0.65, or a little over $\frac{5}{8}$ of an inch, so a $\frac{5}{8}$-inch drill will do nicely. With a 1-inch tap we have $1 - \frac{1}{8} = \frac{7}{8}$-inch drill, which is a little large but leaves enough thread for most cases.

A tap should be between 0.002 and 0.003 inch large for clearance between top and bottom of threads.

Dimensions for Twist Drills

FOR HOLES TO BE THREADED WITH AMERICAN THREAD TAPS $\frac{1}{16}$ to $\frac{1}{64}$ INCH DIAMETER

Diameter Inches	No. of Threads to the Inch	Exact Diameter Bottom of Thread Inches	Gage No. of Drill	Diameter Inches	No. of Threads to the Inch	Exact Diameter Bottom of Thread Inches	Gage No. of Drill
$\frac{1}{16}$	60	.041	57	$\frac{1}{4}$	26	.200	6
$\frac{1}{16}$	64	.042	56	$\frac{5}{64}$	56	.055	53
$\frac{6}{32}$	48	.067	50	$\frac{5}{64}$	60	.056	53
$\frac{8}{32}$	50	.068	50	$\frac{7}{64}$	40	.077	46
$\frac{8}{32}$	56	.071	49	$\frac{7}{64}$	44	.080	45
$\frac{8}{32}$	60	.072	48	$\frac{7}{64}$	48	.082	44
$\frac{1}{8}$	40	.093	41	$\frac{9}{64}$	32	.100	38
$\frac{1}{8}$	44	.096	40	$\frac{9}{64}$	36	.105	36
$\frac{1}{8}$	48	.098	39	$\frac{9}{64}$	40	.108	34
$\frac{6}{32}$	32	.116	31	$\frac{11}{64}$	32	.131	29
$\frac{5}{32}$	36	.120	31	$\frac{11}{64}$	36	.136	28
$\frac{5}{32}$	40	.124	30	$\frac{11}{64}$	40	.139	28
$\frac{8}{15}$	24	.133	29	$\frac{13}{64}$	24	.149	24
$\frac{8}{16}$	28	.141	27	$\frac{13}{64}$	28	.157	21
$\frac{8}{16}$	30	.144	26	$\frac{13}{64}$	32	.162	19
$\frac{8}{16}$	32	.147	25	$\frac{13}{64}$	36	.167	18
$\frac{8}{16}$	36	.152	23	$\frac{15}{64}$	24	.180	13
$\frac{7}{32}$	24	.164	19	$\frac{15}{64}$	28	.188	10
$\frac{7}{32}$	28	.172	16	$\frac{15}{64}$	32	.194	8
$\frac{7}{32}$	32	.178	14	$\frac{15}{64}$	36	.198	7
$\frac{7}{32}$	36	.183	12	$\frac{17}{64}$	18	.193	9
$\frac{1}{4}$	18	.178	14	$\frac{17}{64}$	20	.201	5
$\frac{1}{4}$	20	.185	12	$\frac{17}{64}$	24	.211	3
$\frac{1}{4}$	22	.190	10	$\frac{17}{64}$	26	.216	2
$\frac{1}{4}$	24	.196	8	$\frac{17}{64}$	32	.225	1

Drills and Reamers for Dowel Pins

Sizes of Rod	Drills and Reamers for Drive Fits		Drills for Clearance	
No. of Gage (Stubbs Steel Wire) Dia.	Size of Drill	Dia. of Drill	Dia. of Reamer	Size of Drill	Dia. of Drill
54 .055	No. 55	.052		No. 54	.055
45 .081	" 47	.0785		" 46	.081
33 .112	" 30	.1065	.110	" 33	.113
30 .127	" 28	.120	.125	" 30	.1285
21 .157	" 24	.152	.155	" 22	.157
10 .191	" 13	.185	.189	" 11	.191
.252	C	.242	.250 —.2505	F	.257
.315	5/16 Reamer Drill	.307	.3125—.313	O	.316
V .377	"	.366	.375 —.3755	V	.377
.430	7/16 "	.427	.4375—.438		
.505	1/2 "	.489	.500 —.5005		
.628	5/8 "	.616	.625 —.6255		
.753	3/4 "	.734 (11/16)	.750 —.7505		

DRILL END LENGTHS

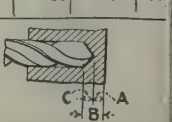
It is often necessary in designing to allow for drilling to a certain depth so as to give the thickness of metal A necessary at the bottom of the hole to withstand pressure.

The table gives the dimension C for usual sizes of drills. This is deducted from B to give the actual thickness of metal at A.

DRILL END LENGTHS

Dia.	C	C in nearest 64ths	Gage No.	Dia.	C	C in Nearest 64ths	Gage No.	Dia.	C	C in Nearest 64ths
2	0.60086	39/64	1	0.2280	0.06850	4/64	41	0.0960	0.02884	2/64
1 13/16	0.58208	37/64	2	0.2210	0.06640	4/64	42	0.0935	0.02809	2/64
1 3/4	0.56331	36/64	3	0.2130	0.06400	4/64	43	0.0890	0.02674	2/64
1 11/16	0.54453	35/64	4	0.2090	0.06279	4/64	44	0.0860	0.02584	2/64
1 5/8	0.52576	34/64	5	0.2055	0.06174	4/64	45	0.0820	0.02464	2/64
1 9/16	0.50698	32/64	6	0.2040	0.06129	4/64	46	0.0810	0.02433	2/64
1 1/2	0.48820	31/64	7	0.2010	0.06039	4/64	47	0.0785	0.02858	2/64
1 7/16	0.46942	30/64	8	0.1990	0.05979	4/64	48	0.0760	0.02283	2/64
1 7/16	0.45065	29/64	9	0.1960	0.05888	4/64	49	0.0730	0.02193	2/64
1 3/8	0.43187	28/64	10	0.1935	0.05813	4/64	50	0.0700	0.02103	2/64
1 3/8	0.41309	27/64	11	0.1910	0.05738	4/64	51	0.0670	0.02013	2/64
1 5/16	0.39431	25/64	12	0.1890	0.05678	4/64	52	0.0635	0.01908	2/64
1 1/4	0.37554	24/64	13	0.1850	0.05558	4/64	53	0.0595	0.01788	2/64
1 3/16	0.35676	23/64	14	0.1820	0.05468	4/64	54	0.0550	0.01652	2/64
1 1/8	0.33798	22/64	15	0.1800	0.05408	4/64	55	0.0520	0.01562	2/64
1 1/16	0.31931	20/64	16	0.1770	0.05318	4/64	56	0.0465	0.01397	2/64
1	0.30046	19/64	17	0.1730	0.05197	4/64	57	0.0430	0.01292	2/64
31/32	0.29104	18/64	18	0.1695	0.05092	4/64	58	0.0420	0.01262	2/64
15/16	0.28165	18/64	19	0.1660	0.04987	3/64	59	0.0410	0.01232	2/64
29/32	0.27226	17/64	20	0.1610	0.04837	3/64	60	0.0400	0.01202	2/64
7/8	0.26288	17/64	21	0.1590	0.04777	3/64	61	0.0390	0.01172	2/64
27/32	0.25349	16/64	22	0.1570	0.04717	3/64	62	0.0380	0.01142	2/64
13/16	0.24410	15/64	23	0.1540	0.04627	3/64	63	0.0370	0.01112	2/64
25/32	0.23471	15/64	24	0.1520	0.04567	3/64	64	0.0360	0.01082	2/64
3/4	0.22532	14/64	25	0.1495	0.04491	3/64	65	0.0350	0.01052	2/64
23/32	0.21593	13/64	26	0.1470	0.04416	3/64	66	0.0330	0.00991	2/64
11/16	0.20655	13/64	27	0.1440	0.04326	3/64	67	0.0320	0.00961	2/64
21/32	0.19716	12/64	28	0.1405	0.04221	3/64	68	0.0310	0.00931	2/64
5/8	0.18777	12/64	29	0.1360	0.04086	3/64	69	0.0293	0.00879	2/64
19/32	0.17838	11/64	30	0.1285	0.03861	3/64	70	0.0280	0.00841	2/64
9/16	0.16900	11/64	31	0.1200	0.03605	3/64	71	0.0260	0.00781	2/64
17/32	0.15960	10/64	32	0.1160	0.03485	3/64	72	0.0250	0.00751	2/64
1/2	0.15022	10/64	33	0.1130	0.03395	3/64	73	0.0240	0.00721	2/64
15/32	0.14083	9/64	34	0.1110	0.03335	3/64	74	0.0225	0.00676	2/64
7/16	0.13144	8/64	35	0.1100	0.03305	3/64	75	0.0210	0.00631	2/64
13/32	0.12205	8/64	36	0.1065	0.03200	3/64	76	0.0200	0.00601	2/64
3/8	0.11266	7/64	37	0.1040	0.03124	3/64	77	0.0180	0.00541	1/64
11/32	0.10327	7/64	38	0.1015	0.03049	3/64	78	0.0160	0.00481	1/64
7/16	0.09388	6/64	39	0.0995	0.02989	3/64	79	0.0145	0.00436	1/64
21/64	0.08450	5/64	40	0.0980	0.02944	3/64	80	0.0135	0.00406	1/64
5/16	0.07511	5/64								
19/64	0.06572	4/64								
9/32	0.05633	4/64								
17/64	0.04942	3/64								
1/8	0.03755	3/64								
7/64	0.02817	2/64								
1/16	0.01878	1/64								
1/32	0.00939	1/64								

Formula, $C = \frac{0.60086 \text{ Diam.}}{2}$



SPEED AND FEED TABLES FOR DRILLING MACHINES

In the use of modern high-speed drills, unless the operator is given definite instructions or provided with tables, the speeds and feeds are likely to be much less than the tools are capable of standing. Good high-speed drills will stand being forced far beyond what appears reasonable to the uninformed operator.

Two speed and feed tables are shown herewith. Table 1 is merely a copy of the drilling specifications supplied for use in connection with a certain gear-driven machine, while Table 2 is made to correspond with the range of speeds and feeds of an older machine of the belt-driven type.

TABLE 1.—DRILL SPEEDS AND FEEDS FOR GEAR-DRIVEN MACHINES

Size, Drill in Inches	Speed in R.p.m.		Feed
	Steel	Cast Iron	
$\frac{1}{2}$	458	610	0.007
$\frac{5}{8}$	366	459	0.011
$\frac{3}{4}$	305	383	0.011
$\frac{7}{8}$	262	328	0.015
1	229	287	0.015
$1\frac{1}{8}$	204	255	0.015
$1\frac{1}{4}$	183	229	0.015
$1\frac{1}{2}$	153	191	0.015
$1\frac{3}{4}$	127	164	0.015
2	104	143	0.015
$2\frac{1}{4}$	89	118	0.015
$2\frac{1}{2}$	76	106	0.025
$2\frac{3}{4}$	68	95	0.025
3	60	84	0.025

TABLE 2.—DRILL SPEEDS AND FEEDS FOR BELT-DRIVEN MACHINES

Gear Speed		R.p.m.	Size Drill in Inches		Feed
			Steel	Cast Iron	
Back Gear In	Low....	15			
	Second.	25			
	Third...	40			
	High...	58	$2\frac{1}{2}$		0.023
Back Gear Out	Low....	80	$1\frac{7}{8}$ — $2\frac{1}{4}$	$2\frac{1}{8}$ — $2\frac{1}{2}$	0.017
	Second.	130	$1\frac{1}{8}$ — $1\frac{3}{4}$	$1\frac{1}{4}$ — 2	0.017
	Third...	210	$\frac{3}{4}$ — $1\frac{1}{16}$	1 — $1\frac{3}{16}$	0.010
	High...	310	$\frac{11}{16}$ and under	$\frac{15}{16}$ and under	0.010

A CUTTING COMPOUND FOR DRILLING HARD SPOTS IN STEEL

An old-time compound for use in drilling hard steel has proved successful in electric welds in 5 per cent nickel steel, after turpentine and other compounds had failed. The compound is

1 part powdered sulphur
1 part cylinder oil
2 parts castor oil

STANDARD TAP DIMENSIONS

STANDARD TAP SIZES

The following tables show the sizes agreed upon by most tap manufacturers and may be considered as standards of 1925.

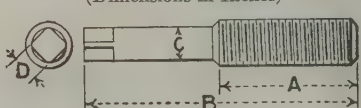
Basic Thread Dimensions and Tap Drill Sizes

AMERICAN COARSE THREAD

Nominal Size	Outside Diameter in Inches	Pitch Diameter in Inches	Root Diameter in Inches	Commercial Tap Drill to Produce Approx. 75% Full Thread	Decimal Equivalent of Tap Drill
1/8 — 9	0.9375	0.8654	0.7932	13/64	0.8281
1 — 8	1.0000	0.9188	0.8376	7/8	0.8750
12	1.0000	0.9459	0.8918	59/64	0.9219
14	1.0000	0.9536	0.9072	15/16	0.9375
27	1.0000	0.9759	0.9519	31/32	0.9687
1 1/8 — 7	1.1250	1.0322	0.9394	63/64	0.9844
12	1.1250	1.0709	1.0168	1 1/64	1.0469
1 1/4 — 7	1.2500	1.1572	1.0644	1 3/32	1.1094
12	1.2500	1.1959	1.1418	1 11/64	1.1719
1 3/8 — 6	1.3750	1.2668	1.1585	1 7/32	1.2187
12	1.3750	1.3209	1.2668	1 19/64	1.2969
1 1/2 — 6	1.5000	1.3917	1.2835	1 11/32	1.3437
12	1.5000	1.4459	1.3918	1 27/64	1.4219
1 5/8 — 5 1/2	1.6250	1.5070	1.3888	1 7/16	1.4531
1 3/4 — 5	1.7500	1.6201	1.4902	1 31/64	1.5625
1 7/8 — 5	1.8750	1.7451	1.6152	1 47/64	1.6875
2 — 4 1/2	2.0000	1.8557	1.7113	1 49/64	1.7812
2 1/8 — 4 1/2	2.1250	1.9807	1.8363	1 57/64	1.9062
2 1/4 — 4 1/2	2.2500	2.1057	1.9613	2 1/32	2.0312
2 3/8 — 4	2.3750	2.2126	2.0502	2 1/16	2.1250
2 1/2 — 4	2.5000	2.3376	2.1752	2 1/8	2.2500
2 5/8 — 4	2.7500	2.5876	2.4252	2 1/4	2.5000
3 — 3 1/2	3.0000	2.8145	2.6288	2 43/64	2.7187
3 1/4 — 3 1/2	3.2500	3.0645	2.8788	2 59/64	2.9687
3 1/2 — 3 1/2	3.5000	3.3002	3.1003	3 5/16	3.1875
3 1/2 —3	3.7500	3.5335	3.3170	3 7/16	3.4375
4 3	4.0000	3.7835	3.5670	3 11/16	3.6875

Dimensions of Standard Hand Taps

Formula: Diameter of shank = O. D. of tap − (Std. V pitch × 1.6)
Size of square = diameter of shank × 0.75
(Dimensions in Inches)



Diam. of Tap	Length		Diam. of Shank C	Size of Square D	Diam. of Tap	Length		Diam. of Shank	Size of Square
	Thread A	Overall B				Thread	Overall		
1/4	1	2 1/2	0.2530	0.1897	1 1/2	2 9/16	5 3/4	1.0215	0.7661
5/16	1	2 1/2	0.2686	0.2015	1 9/16	2 9/16	5 3/4	1.0527	0.7895
3/8	1	2 1/2	0.2843	0.2132	1 5/8	2 9/16	5 3/4	1.0840	0.8130
7/16	1	2 1/2	0.2999	0.2249	1 11/16	3	6 1/16	1.1083	0.8312
1/2	1 1/8	2 23/32	0.3155	0.2366	1 3/4	3	6 1/16	1.1395	0.8546
9/16	1 1/8	2 23/32	0.3311	0.2483	1 13/16	3	6 1/16	1.1703	0.8781
5/8	1 1/8	2 23/32	0.3468	0.2601	1 7/8	3	6 3/8	1.2333	0.9250
11/16	1 1/8	2 23/32	0.3624	0.2718	1 15/16	3	6 3/8	1.2645	0.9484
3/4	1 1/4	2 15/16	0.3785	0.2839	2	3 3/16	6 11/16	1.3050	0.9787
13/16	1 1/4	2 15/16	0.3941	0.2956	2 1/16	3 3/16	6 11/16	1.3362	1.0021
7/8	1 1/4	2 15/16	0.4098	0.3074	2 1/8	3 3/16	7	1.4300	1.0725
					2 3/16	3 3/16	7	1.4612	1.0959
15/16	1 1/2	2 1/8	0.2750	0.2062	2 1/4	3 3/16	7 5/16	1.5105	1.1329
1	1 1/2	2 1/8	0.2906	0.2179	2 5/16	3 3/16	7 5/16	1.5507	1.1630
1 1/16	1 1/2	2 1/8	0.3062	0.2296	2	3 3/16	7 5/8	1.6445	1.2334
1 1/8	1 1/4	2 1/16	0.3218	0.2414	2 7/32	3 3/16	7 5/8	1.6757	1.2568
1 3/16	1 7/16	3 3/32	0.3223	0.2424	2 1/8	3 3/16	8	1.7694	1.3271
1 1/4	1 7/16	3 3/32	0.3388	0.2541	2 3/32	3 3/16	8	1.8007	1.3505
1 5/16	1 7/16	3 3/32	0.3544	0.2658	2 1/4	3 3/16	8 1/4	1.8944	1.4208
1 3/8	1 7/16	3 3/32	0.3700	0.2775	2 5/16	3 3/16	8 1/4	1.9257	1.4443
1 7/16	1 5/8	3 3/16	0.3667	0.2750	2 3/8	4	8 1/2	2.0194	1.5146
1 1/2	1 5/8	3 3/16	0.3823	0.2867	2 7/32	4	8 1/2	2.0507	1.5380
1 9/16	1 5/8	3 3/16	0.3979	0.2984	2 1/2	4	8 1/2	2.1000	1.5750
1 5/8	1 5/8	3 3/16	0.4135	0.3101	2 17/32	4	8 1/4	2.1313	1.5984
1 11/16	1 11/16	3 7/32	0.4292	0.3219	2 5/8	4	8 1/4	2.2250	1.6687
1 3/4	1 11/16	3 7/32	0.4448	0.3336	2 11/32	4	8 1/4	2.2563	1.6922
1 13/16	1 11/16	3 7/32	0.4604	0.3453	2 3/4	4	9 1/4	2.3500	1.7625
1 7/8	1 11/16	3 7/32	0.4760	0.3570	2 13/32	4	9 1/4	2.3813	1.7859
1 15/16	1 11/16	3 7/32	0.4796	0.3597	2 7/8	4	9 1/4	2.4750	1.8562
2	1 11/16	3 7/32	0.4952	0.3714	2 15/32	4	9 1/4	2.5063	1.8797
2 1/16	1 11/16	3 7/32	0.5108	0.3831	3	4 9/16	9 1/4	2.5429	1.9072
2 1/8	1 11/16	4 1/4	0.5421	0.4066	3 1/32	4 9/16	9 1/4	2.5742	1.9306
2 3/16	1 11/16	4 1/4	0.5733	0.4300	3 1/8	4 9/16	9 1/4	2.6679	2.0009
2 1/4	2	4 1/4	0.5900	0.4425	3 3/32	4 9/16	9 1/4	2.6992	2.0244
2 5/16	2	4 1/4	0.6212	0.4659	3 1/4	4 9/16	10	2.7929	2.0946
2 3/8	2	4 1/2	0.6525	0.4894	3 5/32	4 9/16	10	2.8242	2.1181
2 7/16	2	4 1/2	0.6837	0.5128	3 3/8	4 9/16	10	2.8827	2.1620
2 1/2	2 7/32	4 1/16	0.6973	0.5230	3 13/32	4 9/16	10	2.9140	2.1855
2 9/16	2 7/32	4 1/16	0.7285	0.5464	3 7/16	4 11/16	10 1/2	3.0077	2.2557
2 5/8	2 7/32	4 3/32	0.7598	0.5698	3 1/2	4 11/16	10 1/2	3.0390	2.2792
2 11/16	2 7/32	4 3/32	0.7910	0.5932	3 9/16	4 11/16	10 1/2	3.1327	2.3495
2 3/4	2 9/16	5 1/16	0.8000	0.6000	3 17/32	4 11/16	10 1/2	3.1640	2.3730
2 13/16	2 9/16	5 1/16	0.8312	0.6234	3 5/8	5 1/16	10 1/2	3.2167	2.4125
2 7/8	2 9/16	5 1/16	0.8625	0.6469	3 19/32	5 1/16	10 1/2	3.2479	2.4359
2 15/16	2 9/16	5 1/16	0.8965	0.6724	3 5/8	5 1/16	10 1/2	3.3417	2.5062
3	2 9/16	5 1/16	0.9277	0.6958	3 21/32	5 1/16	10 1/2	3.3729	2.5297
3 1/16	2 9/16	5 1/16	0.9590	0.7192	4	5 1/16	10 1/2	3.4667	2.6000

For tolerance, see page 131.

Commercial Tolerances for Hand Taps and Pulley Taps

American Coarse Thread Standard

(Dimensions in Inches)

Size	Basic		Tap Measurements					
			Outside Diameter			Pitch Diameter		
	Outside Diam.	Pitch Diam.	Minimum	Maximum	Tolerance	Minimum	Maximum	Tolerance
$\frac{1}{4}$ −20	0.2500	0.2175	0.2510	0.2535	0.0025	0.2180	0.2200	0.0020
$\frac{5}{16}$−18	0.3125	0.2764	0.3135	0.3160	0.0025	0.2769	0.2789	0.0020
$\frac{3}{8}$ −16	0.3750	0.3344	0.3760	0.3785	0.0025	0.3349	0.3369	0.0020
$\frac{7}{16}$−14	0.4375	0.3911	0.4385	0.4415	0.0030	0.3916	0.3941	0.0025
$\frac{1}{2}$ −13	0.5000	0.4500	0.5010	0.5040	0.0030	0.4505	0.4530	0.0025
$\frac{9}{16}$−12	0.5625	0.5084	0.5635	0.5665	0.0030	0.5089	0.5114	0.0025
$\frac{5}{8}$ −11	0.6250	0.5660	0.6260	0.6290	0.0030	0.5665	0.5690	0.0025
$\frac{3}{4}$ −10	0.7500	0.6850	0.7510	0.7550	0.0040	0.6855	0.6885	0.0030
$\frac{7}{8}$ − 9	0.8750	0.8028	0.8760	0.8800	0.0040	0.8033	0.8063	0.0030
1 − 8	1.0000	0.9188	1.0010	1.0050	0.0040	0.9193	0.9223	0.0030
$1\frac{1}{8}$ − 7	1.1250	1.0322	1.1265	1.1310	0.0045	1.0327	1.0362	0.0035
$1\frac{1}{4}$ − 7	1.2500	1.1572	1.2515	1.2560	0.0045	1.1577	1.1612	0.0035
$1\frac{3}{8}$ − 6	1.3750	1.2668	1.3765	1.3810	0.0045	1.2673	1.2708	0.0035
$1\frac{1}{2}$ − 6	1.5000	1.3917	1.5015	1.5060	0.0045	1.3922	1.3957	0.0035
$1\frac{5}{8}$ − $5\frac{1}{2}$	1.6250	1.5069	1.6265	1.6320	0.0055	1.5079	1.5119	0.0040
$1\frac{3}{4}$ − 5	1.7500	1.6201	1.7515	1.7570	0.0055	1.6211	1.6251	0.0040
$1\frac{7}{8}$ − 5	1.8750	1.7451	1.8765	1.8820	0.0055	1.7461	1.7501	0.0040
2 − $4\frac{1}{2}$	2.0000	1.8557	2.0015	2.0070	0.0055	1.8567	1.8607	0.0040
$2\frac{1}{4}$ − $4\frac{1}{2}$	2.1250	1.9807	2.1270	2.1330	0.0060	1.9817	1.9862	0.0045
$2\frac{1}{2}$ − $4\frac{1}{2}$	2.2500	2.1057	2.2520	2.2580	0.0060	2.1067	2.1112	0.0045
$2\frac{3}{4}$ − 4	2.3750	2.2126	2.3770	2.3830	0.0060	2.2136	2.2181	0.0045
$2\frac{1}{2}$ − 4	2.5000	2.3376	2.5020	2.5080	0.0060	2.3386	2.3431	0.0045
$2\frac{3}{4}$ − 4	2.6250	2.4626	2.6270	2.6340	0.0070	2.4636	2.4686	0.0050
$2\frac{1}{2}$ − 4	2.7500	2.5876	2.7520	2.7590	0.0070	2.5886	2.5936	0.0050
$2\frac{3}{4}$ − $3\frac{1}{2}$	2.8750	2.6894	2.8770	2.8840	0.0070	2.6904	2.6954	0.0050
3 − $3\frac{1}{2}$	3.0000	2.8144	3.0020	3.0090	0.0070	2.8154	2.8204	0.0050

Lead Tolerance

A maximum lead error of plus or minus 0.003 inch in 1 inch of thread is permitted.

Tolerances for All Hand Taps

Length overall, $\frac{1}{4}$ to $1\frac{1}{2}$ inch inclusive	Plus or minus $\frac{1}{32}$ inch
Length overall, $1\frac{1}{16}$ to 4 inches inclusive	Plus or minus $\frac{1}{16}$ inch
Length of thread	Plus or minus $\frac{3}{64}$ inch
Diameter of shank to 1 inch inclusive	Size to size minus 0.005 inch
Diameter of shank 1 $\frac{1}{16}$ to 2 inches inclusive	Size to size minus 0.007 inch
Diameter of shank over 2 inches	Size to size minus 0.009 inch
Size of square, $\frac{1}{2}$ inch and smaller	Size to size minus 0.004 inch
Size of square, $\frac{23}{64}$ to 1 inch inclusive	Size to size minus 0.006 inch
Size of square, 1 $\frac{1}{32}$ to 2 inches inclusive	Size to size minus 0.008 inch
Size of square, 2 $\frac{1}{32}$ to 4 inches inclusive	Size to size minus 0.010 inch

Commercial Tolerances for Hand Taps and Taps for B. & S Holder

American Fine Thread Standard

(Dimensions in Inches)

Size	Basic		Tap Measurements					
			Outside Diameter			Pitch Diameter		
	Outside Diam.	Pitch Diam.	Minimum	Maximum	Tolerance	Minimum	Maximum	Tolerance
1/4-28	0.2500	0.2268	0.2510	0.2535	0.0025	0.2273	0.2288	0.001
5/16-24	0.3125	0.2854	0.3135	0.3160	0.0025	0.2859	0.2874	0.001
3/8-24	0.3750	0.3479	0.3760	0.3785	0.0025	0.3484	0.3499	0.001
7/16-20	0.4375	0.4050	0.4385	0.4415	0.0030	0.4055	0.4075	0.002
1/2-20	0.5000	0.4675	0.5010	0.5040	0.0030	0.4680	0.4700	0.002
9/16-18	0.5625	0.5264	0.5635	0.5665	0.0030	0.5269	0.5289	0.002
5/8-18	0.6250	0.5889	0.6260	0.6290	0.0030	0.5894	0.5914	0.002
11/16-16	0.6875	0.6469	0.6885	0.6925	0.0040	0.6474	0.6499	0.002
3/4-16	0.7500	0.7094	0.7510	0.7550	0.0040	0.7099	0.7124	0.002
7/8-14	0.8750	0.8286	0.8760	0.8800	0.0040	0.8291	0.8316	0.002
7/8-18	0.8750	0.8389	0.8760	0.8800	0.0040	0.8394	0.8419	0.002
1 -14	1.0000	0.9536	1.0010	1.0050	0.0040	0.9541	0.9566	0.002
1 1/16-12	1.1250	1.0709	1.1265	1.1310	0.0045	1.0714	1.0744	0.003
1 1/4-12	1.2500	1.1959	1.2515	1.2560	0.0045	1.1964	1.1994	0.003
1 3/8-12	1.3750	1.3209	1.3765	1.3810	0.0045	1.3214	1.3244	0.003
1 1/2-12	1.5000	1.4459	1.5015	1.5060	0.0045	1.4464	1.4494	0.003

*Taps over 1½ Inches with 10 or More Threads per Inch

(Dimensions in Inches)

Size	Tap Measurements					
	Outside Diameter			Pitch Diameter		
	Min. = Basic Plus	Max. = Basic Plus	Tolerance	Min. = Basic Plus	Max. = Basic. Plus	Tolerance
1 3/4 to 2 inches inclusive	0.0015	0.0060	0.0045	0.0005	0.0035	0.003
2 1/4 to 3 inches inclusive	0.0015	0.0060	0.0045	0.0005	0.0040	0.003
3 1/4 to 4 inches inclusive	0.0015	0.0070	0.0055	0.0005	0.0050	0.004

* For taps over 1½ inches with less than 10 threads per inch use tolerance for American Coarse Thread Taps.

Lead Tolerance

A maximum lead error of plus or minus .003 inch in 1 inch of thread permitted.

Standard Dimensions of Nut Taps

Diam. of Tap Inches	No. of Threads per Inch		Diam. of Shank in Inches	Size of Square in Inches	Length of Thread in Inches		Length Overall in Inches
	Coarse	Fine			Coarse	Fine	
3/16	24, 32		0.133	0.100	1 3/8	*1	4 1/2
1/4	20	28	0.185	0.139	1 1/2	1 1/2	5
5/16	18	24	0.240	0.180	1 13/16	1 3/4	5 1/2
3/8	16	24	0.294	0.220	2	1 1/2	6
7/16	14	20	0.345	0.259	2 1/8	1 3/4	6 1/2
1/2	13	20	0.400	0.300	2 1/4	1 7/8	7
9/16	12	18	0.450	0.337	2 1/4	2	7 1/2
5/8	11	18	0.503	0.377	3	2 1/4	8
11/16	11	16	0.565	0.424	3	2 1/4	8 1/2
3/4	10	16	0.616	0.462	3 1/4	2 1/2	9
13/16	10		0.679	0.509	3 1/4		9 1/2
7/8	9	14, 18	0.727	0.545	3 1/2	2 3/4	10
15/16	9		0.789	0.592	3 5/8		10 1/2
1	8	14	0.834	0.625	4	3	11
1 1/8	7	12	0.933	0.700	4 1/8	3 1/4	11 1/2
1 1/4	7	12	1.058	0.793	4 1/2	3 1/2	12
1 3/8	6	12	1.153	0.865	5 1/8	4	12 1/2
1 1/2	6	12	1.278	0.958	5 1/8	4	13
1 5/8	5 1/2		1.383	1.037	5 1/2		13 1/2
1 3/4	5		1.484	1.113	5 1/2		14
1 7/8	5		1.609	1.207	5 1/2		14 1/2
2	4 1/2		1.705	1.279	6 1/8		15
2 1/4	4 1/2		1.828	1.371	6 1/8		15 1/2
2 1/2	4 1/2		1.953	1.465	6 1/8		16
2 3/4	4		2.042	1.531	6 1/8		16 1/2
2 7/8	4		2.167	1.625	6 1/8		17

* For 32 threads per inch.

Tolerances

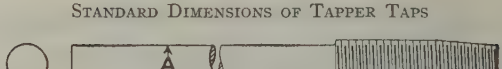
Diam. of Tap in Inches	Shank	Square
3/16– 1/4	Size to size minus 0.005 inches	Size to size minus 0.004 inches
5/16–1	Size to size minus 0.006 inches	Size to size minus 0.006 inches
1 1/8 –2	Size to size minus 0.008 inches	Size to size minus 0.008 inches
2 1/8 –2 1/2	Size to size minus 0.010 inches	Size to size minus 0.010 inches

Formulae

Diam. of Tap in Inches	Diam. of Shank
3/16– 1/2	American basic root diam.
5/8–1	American basic root diam. minus 0.004 inches
1 1/8 –2	American basic root diam. minus 0.006 inches
2 1/8 –2 1/2	American basic root diam. minus 0.008 inches

Size square = Diam. of shank × 0.75

Standard Dimensions of Tapper Taps



Diam. of Tap in Inches	No. of Threads per Inch		Diameter of Shank in Inches *A*	Length of Thread in Inches *B*		Length Overall in Inches
	Coarse	Fine		Coarse	Fine	
1/4	20	28	0.185	1 5/8	1 1/2	12 & 15
5/16	18	24	0.240	1 13/16	1 5/8	12 & 15
3/8	16	24	0.294	2	1 5/8	12 & 15
7/16	14	20	0.345	2 1/16	1 13/16	12 & 15
1/2	13	20	0.400	2 1/4	1 13/16	12 & 15
9/16	12	18	0.450	2 1/2	1 15/16	12 & 15
5/8	11	18	0.503	2 5/8	1 15/16	12 & 15
11/16	11	16	0.565	2 1/2	1 15/16	12 & 15
3/4	10	16	0.616	2 3/4	2	12 & 15
13/16	10		0.679	2 3/4		12 & 15
7/8	9	14, 18	0.727	3	2	12 & 15
15/16	9		0.789	3		12 & 15
1	8	14	0.834	3 1/4	2 5/8	12 & 15
1 1/8	7	12	0.933	3 1/2	2 5/8	15
1 1/4	7	12	1.058	3 1/2	2 5/8	15
1 3/8	6	12	1.153	4	3	15
1 1/2	6	12	1.278	4	3	15
1 5/8	5 1/2		1.383	4		15
1 3/4	5		1.484	4 1/2		15
1 7/8	5		1.609	4 1/2		15
2	4 1/2		1.705	4 1/2		15

Tolerances

Diam. of shank 1/4 to 1/2 inch inclusive = Size to size minus 0.005 incl
Diam. of shank 9/16 to 1 inch inclusive = Size to size minus 0.006 incl
Diam. of shank 1 1/8 to 2 inches inclusive = Size to size minus 0.008 incl

Formulae

Sizes 1/4 to 1/2 inch inclusive diam. of shank = American basic root diam
Sizes 9/16 to 1 inch inclusive diam. of shank = American basic root diam minus 0.004 incl
Sizes 1 1/8 to 2 inches inclusive diameter of shank = American basic root diam minus 0.006 incl

Commercial Tolerances for Nut and Tapper Taps

American Coarse Thread Standard

(Dimensions in Inches)

Size	Basic		Tap Measurements					
			Outside Diameter			Pitch Diameter		
	Outside Diam.	Pitch Diam.	Minimum	Maximum	Tolerance	Minimum	Maximum	Tolerance
1/4 —20	0.2500	0.2175	0.2520	0.2550	0.0030	0.2190	0.2215	0.0025
5/16—18	0.3125	0.2764	0.3145	0.3175	0.0030	0.2779	0.2804	0.0025
3/8 —16	0.3750	0.3344	0.3770	0.3800	0.0030	0.3359	0.3384	0.0025
7/16—14	0.4375	0.3911	0.4395	0.4435	0.0040	0.3926	0.3956	0.0030
1/2 —13	0.5000	0.4500	0.5020	0.5060	0.0040	0.4515	0.4545	0.0030
9/16—12	0.5625	0.5084	0.5650	0.5690	0.0040	0.5104	0.5134	0.0030
5/8 —11	0.6250	0.5660	0.6275	0.6315	0.0040	0.5680	0.5710	0.0030
3/4 —10	0.7500	0.6850	0.7525	0.7570	0.0045	0.6870	0.6905	0.0035
7/8 — 9	0.8750	0.8028	0.8775	0.8820	0.0045	0.8048	0.8083	0.0035
1 — 8	1.0000	0.9188	1.0025	1.0070	0.0045	0.9208	0.9243	0.0035
1 1/8 — 7	1.1250	1.0322	1.1280	1.1330	0.0050	1.0347	1.0387	0.0040
1 1/4 — 7	1.2500	1.1572	1.2530	1.2580	0.0050	1.1597	1.1637	0.0040
1 3/8 — 6	1.3750	1.2668	1.3780	1.3830	0.0050	1.2693	1.2733	0.0040
1 1/2 — 6	1.5000	1.3917	1.5030	1.5080	0.0050	1.3942	1.3982	0.0040
1 5/8 — 5 1/2	1.6250	1.5069	1.6280	1.6340	0.0060	1.5094	1.5130	0.0045
1 3/4 — 5	1.7500	1.6201	1.7530	1.7590	0.0060	1.6226	1.6271	0.0045
1 7/8 — 5	1.8750	1.7451	1.8780	1.8840	0.0060	1.7476	1.7521	0.0045
2 — 4 1/2	2.0000	1.8557	2.0030	2.0090	0.0060	1.8582	1.8627	0.0045
2 1/4 — 4 1/2	2.1250	1.9807	2.1290	2.1360	0.0070	1.9837	1.9887	0.0050
2 1/4 — 4 1/2	2.2500	2.1057	2.2540	2.2610	0.0070	2.1087	2.1137	0.0050
2 3/8 — 4	2.3750	2.2126	2.3790	2.3860	0.0070	2.2156	2.2206	0.0050
2 1/2 — 4	2.5000	2.3376	2.5040	2.5110	0.0070	2.3406	2.3456	0.0050
2 5/8 — 4	2.6250	2.4626	2.6290	2.6370	0.0080	2.4656	2.4711	0.0055
2 3/4 — 4	2.7500	2.5876	2.7540	2.7620	0.0080	2.5906	2.5961	0.0055
2 7/8 — 3 1/2	2.8750	2.6894	2.8790	2.8870	0.0080	2.6924	2.6979	0.0055
3 — 3 1/2	3.0000	2.8144	3.0040	3.0120	0.0080	2.8174	2.8229	0.0055

Lead Tolerance

A maximum lead error of plus or minus 0.003 inch in 1 inch of thread is permitted.

Taps with pitch coarser than American Fine Standard will take Coarse Standard tolerances. Those with finer pitch take Fine Standard tolerances.

Commercial Tolerances for Nut and Tapper Taps

AMERICAN FINE THREAD STANDARD

(Dimensions in Inches)

Size	Basic		Tap Measurements					
			Outside Diameter			Pitch Diameter		
	Outside Diam.	Pitch Diam.	Minimum	Maximum	Tolerance	Minimum	Maximum	Tolerance
1/4 −28	0.2500	0.2268	0.2510	0.2535	0.0025	0.2273	0.2288	0.0015
5/16−24	0.3125	0.2854	0.3135	0.3160	0.0025	0.2859	0.2874	0.0015
3/8 −24	0.3750	0.3479	0.3760	0.3785	0.0025	0.3484	0.3499	0.0015
7/16−20	0.4375	0.4050	0.4385	0.4415	0.0030	0.4055	0.4075	0.0020
1/2 −20	0.5000	0.4675	0.5010	0.5040	0.0030	0.4680	0.4700	0.0020
9/16−18	0.5625	0.5264	0.5635	0.5665	0.0030	0.5269	0.5289	0.0020
5/8 −18	0.6250	0.5889	0.6260	0.6290	0.0030	0.5894	0.5914	0.0020
11/16−16	0.6875	0.6469	0.6885	0.6925	0.0040	0.6474	0.6490	0.0025
3/4 −16	0.7500	0.7094	0.7510	0.7550	0.0040	0.7099	0.7124	0.0025
13/16−14	0.8750	0.8286	0.8760	0.8800	0.0040	0.8291	0.8316	0.0025
7/8 −18	0.8750	0.8389	0.8760	0.8800	0.0040	0.8394	0.8419	0.0025
1 −14	1.0000	0.9536	1.0010	1.0050	0.0040	0.9541	0.9566	0.0025
1 1/8 −12	1.1250	1.0709	1.1265	1.1310	0.0045	1.0714	1.0744	0.0030
1 1/4 −12	1.2500	1.1959	1.2515	1.2560	0.0045	1.1964	1.1994	0.0030
1 3/8 −12	1.3750	1.3209	1.3765	1.3810	0.0045	1.3214	1.3244	0.0030
1 1/2 −12	1.5000	1.4459	1.5015	1.5060	0.0045	1.4464	1.4494	0.0030

AMERICAN STANDARD FOR SCREWS

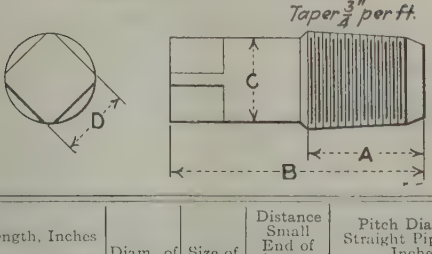
2–56	0.086	0.0744	0.0875	0.0900	0.0025	0.0754	0.0774	0.0020
2–64	0.086	0.0759	0.0875	0.0900	0.0025	0.0769	0.0789	0.0020
3–48	0.099	0.0855	0.1005	0.1030	0.0025	0.0865	0.0885	0.0020
3–56	0.099	0.0874	0.1005	0.1030	0.0025	0.0884	0.0904	0.0020
4–36	0.112	0.0940	0.1140	0.1165	0.0025	0.0955	0.0975	0.0020
4–40	0.112	0.0958	0.1140	0.1165	0.0025	0.0973	0.0993	0.0020
5–40	0.125	0.1088	0.1270	0.1295	0.0025	0.1103	0.1123	0.0020
6–32	0.138	0.1177	0.1400	0.1425	0.0025	0.1192	0.1212	0.0020
6–40	0.138	0.1218	0.1400	0.1425	0.0025	0.1233	0.1253	0.0020
8–32	0.164	0.1437	0.1660	0.1685	0.0025	0.1452	0.1472	0.0020
10–24	0.190	0.1620	0.1920	0.1945	0.0025	0.1644	0.1664	0.0020
10–32	0.190	0.1607	0.1920	0.1945	0.0025	0.1712	0.1732	0.0020
12–24	0.216	0.1889	0.2180	0.2205	0.0025	0.1904	0.1924	0.0020

Lead Tolerance

A maximum lead error of plus or minus 0.003 inch in 1 inch of thread is permitted.

Taps with pitch coarser than Fine Standard will take Coarse Standard tolerances. Those with finer pitch take Fine Standard tolerances.

Dimensions of Pipe Taps



Nominal Sizes Inches	Length, Inches: Thread A	Length, Inches: Overall B	Diam. of Shank Inches C	Size of Square Inches D	Distance Small End of Briggs Standard Tap Projects through Gage	Pitch Diam. of Straight Pipe Tap, Inches: Basic	Minimum	Maximum
$\frac{1}{8}$	$\frac{3}{4}$	$2\frac{1}{8}$	0.3125	0.234	0.312	0.3748	0.3733	0.3763
			0.4375	0.328				
$\frac{1}{4}$	$1\frac{1}{16}$	$2\frac{7}{16}$	0.4375	0.328	0.459	0.4899	0.4884	0.4914
			0.5625	0.421				
$\frac{3}{8}$	$1\frac{1}{16}$	$2\frac{9}{16}$	0.5625	0.421	0.454	0.6270	0.6253	0.6288
			0.7000	0.531				
$\frac{1}{2}$	$1\frac{3}{8}$	$3\frac{1}{4}$	0.6875	0.515	0.579	0.7784	0.7767	0.7802
			0.8650	0.640				
$\frac{5}{8}$	$1\frac{3}{8}$	$3\frac{9}{16}$	0.8125	0.594				
			0.9270	0.687				
$\frac{3}{4}$	$1\frac{3}{8}$	$3\frac{1}{2}$	0.9063	0.679	0.565	0.9889	0.9869	0.9909
			1.0750	0.812				
$\frac{7}{8}$	$1\frac{5}{16}$	$3\frac{1}{2}$	1.0937	0.812				
1	$1\frac{3}{8}$	$3\frac{3}{4}$	1.1250	0.843	0.678	1.2386	1.2366	1.2406
$1\frac{1}{4}$	$1\frac{3}{8}$	4	1.3125	0.984	0.686	1.5834	1.5811	1.5856
$1\frac{1}{2}$	$1\frac{3}{8}$	$4\frac{1}{4}$	1.5000	1.125	0.699	1.8223	1.8201	1.8246
$1\frac{3}{4}$	$1\frac{3}{8}$	$4\frac{3}{4}$	1.6250	1.218				
2	$1\frac{3}{8}$	$4\frac{3}{4}$	1.8750	1.406	0.667	2.2963	2.2938	2.2988
$2\frac{1}{2}$	$2\frac{1}{2}$	5	2.0000	1.500				
$2\frac{1}{2}$	$2\frac{5}{16}$	$5\frac{1}{2}$	2.2500	1.687	0.925	2.7622	2.7594	2.7649
$2\frac{1}{2}$	$2\frac{5}{16}$	$5\frac{3}{4}$	2.3750	1.781				
3	$2\frac{3}{8}$	6	2.6250	1.968	0.925	3.3885	3.3858	3.3913
$3\frac{1}{2}$	$2\frac{3}{8}$	$6\frac{1}{2}$	2.7500	2.062				
$3\frac{1}{2}$	$2\frac{11}{16}$	$6\frac{1}{2}$	2.8125	2.108	0.938	3.8888	3.8861	3.8916
$3\frac{1}{2}$	$2\frac{11}{16}$	$6\frac{3}{4}$	2.8750	2.156				
4	$2\frac{1}{4}$	$6\frac{1}{4}$	3.0000	2.250	0.950	4.3871	4.3844	4.3899

Tolerances

Length overall, $\frac{1}{8}$ to $\frac{3}{4}$ inch inclusive	Plus or minus $\frac{1}{32}$ inch
Length overall, $\frac{7}{8}$ to 4 inches inclusive	Plus or minus $\frac{1}{16}$ inch
Length of thread	Plus or minus $\frac{1}{32}$ inch
Diameter of shank to $\frac{1}{2}$ inch inclusive	Size to size minus 0.007 inch
Diameter of shank over $\frac{1}{2}$ inch	Size to size minus 0.009 inch
Size of square to $\frac{1}{2}$ inch inclusive	Size to size minus 0.006 inch
Size of square over $\frac{1}{2}$ inch	Size to size minus 0.010 inch
Distance projecting through gage, $\frac{1}{8}$ to $\frac{3}{4}$ inch inclusive	Plus or minus $\frac{1}{16}$ inch
Distance projecting through gage, 1 to 3 inches inclusive	Plus or minus $\frac{1}{32}$ inch
Distance projecting through gage, $3\frac{1}{2}$ inches and over	Plus or minus $\frac{1}{8}$ inch

Commercial Tolerances for Stay Bolt Taps
American Form of Thread
(Dimensions in Inches)

Size	Basic		Tap Measurements					
			Outside Diameter			Pitch Diameter		
	Outside Diam.	Pitch Diam.	Minimum	Maximum	Tolerance	Minimum	Maximum	Tolerance
$\frac{3}{8}$–12	0.7500	0.6959	0.7510	0.7550	0.0040	0.6964	0.6994	0.0030
$\frac{7}{16}$–12	0.8750	0.8209	0.8760	0.8800	0.0040	0.8214	0.8244	0.0030
1 –12	1.0000	0.9459	1.0010	1.0050	0.0040	0.9464	0.9494	0.0030
1$\frac{1}{8}$–12	1.1250	1.0709	1.1265	1.1310	0.0045	1.0714	1.0749	0.0035
1$\frac{1}{4}$–12	1.2500	1.1959	1.2515	1.2560	0.0045	1.1964	1.1999	0.0035
1$\frac{3}{8}$–12	1.3750	1.3209	1.3765	1.3810	0.0045	1.3214	1.3249	0.0035
1$\frac{1}{2}$–12	1.5000	1.4459	1.5015	1.5060	0.0045	1.4464	1.4499	0.0035
1$\frac{5}{8}$–12	1.6250	1.5709	1.6265	1.6320	0.0055	1.5719	1.5759	0.0040
1$\frac{3}{4}$–12	1.7500	1.6959	1.7515	1.7570	0.0055	1.6969	1.7009	0.0040
1$\frac{7}{8}$–12	1.8750	1.8209	1.8765	1.8820	0.0055	1.8219	1.8259	0.0040
2 –12	2.0000	1.9459	2.0015	2.0070	0.0055	1.9469	1.9509	0.0040

Lead Tolerance

A maximum lead error of plus or minus 0.003 inch in 1 inch of thread is permitted.

Commercial Tolerances for Ground Thread Taps
American Coarse Thread Standard
(Dimensions in Inches)

Size	Basic		Tap Measurements					
			Outside Diameter			Pitch Diameter		
	Outside Diam.	Pitch Diam.	Minimum	Maximum	Tolerance	Minimum	Maximum	Tolerance
$\frac{1}{4}$–20	0.2500	0.2175	0.2520	0.2535	0.0015	0.2180	0.2190	0.0010
$\frac{5}{16}$–18	0.3125	0.2764	0.3145	0.3100	0.0015	0.2769	0.2779	0.0010
$\frac{3}{8}$–16	0.3750	0.3344	0.3770	0.3785	0.0015	0.3349	0.3359	0.0010
$\frac{7}{16}$–14	0.4375	0.3911	0.4400	0.4415	0.0015	0.3916	0.3926	0.0010
$\frac{1}{2}$ –13	0.5000	0.4500	0.5025	0.5040	0.0015	0.4505	0.4515	0.0010
$\frac{9}{16}$–12	0.5625	0.5084	0.5650	0.5665	0.0015	0.5089	0.5099	0.0010
$\frac{5}{8}$–11	0.6250	0.5660	0.6275	0.6290	0.0015	0.5665	0.5675	0.0010
$\frac{3}{4}$–10	0.7500	0.6850	0.7530	0.7550	0.0020	0.6855	0.6865	0.0010
$\frac{7}{8}$–9	0.8750	0.8028	0.8780	0.8800	0.0020	0.8033	0.8043	0.0010
1 –8	1.0000	0.9188	1.0030	1.0050	0.0020	0.9193	0.9203	0.0010
1$\frac{1}{8}$–7	1.1250	1.0322	1.1290	1.1310	0.0020	1.0327	1.0342	0.0015
1$\frac{1}{4}$–7	1.2500	1.1572	1.2540	1.2560	0.0020	1.1577	1.1592	0.0015
1$\frac{3}{8}$–6	1.3750	1.2668	1.3790	1.3810	0.0020	1.2673	1.2688	0.0015
1$\frac{1}{2}$–6	1.5000	1.3917	1.5040	1.5060	0.0020	1.3922	1.3937	0.0015
1$\frac{3}{4}$–5	1.7500	1.6201	1.7550	1.7570	0.0020	1.6206	1.6221	0.0015
2 –4$\frac{1}{2}$	2.0000	1.8557	2.0050	2.0070	0.0020	1.8562	1.8577	0.0015
2$\frac{1}{4}$–4$\frac{1}{2}$	2.2500	2.1057	2.2560	2.2580	0.0020	2.1062	2.1082	0.0020
2$\frac{1}{2}$–4	2.5000	2.3376	2.5060	2.5080	0.0020	2.3381	2.3401	0.0020
2$\frac{3}{4}$–4	2.7500	2.5876	2.7570	2.7590	0.0020	2.5881	2.5901	0.0020
3 –3$\frac{1}{2}$	3.0000	2.8144	3.0070	3.0090	0.0020	2.8149	2.8169	0.0020

Lead Tolerance—A maximum lead error of plus or minus 0.0005 inch in 1 inch of thread is permitted.

Commercial Tolerances for Ground Thread Taps

AMERICAN FINE THREAD STANDARD

(Dimensions in Inches)

Size	Basic		Tap Measurements					
			Outside Diameter			Pitch Diameter		
	Outside Diam.	Pitch Diam.	Minimum	Maximum	Tolerance	Minimum	Maximum	Tolerance
1/4—28	0.2500	0.2268	0.2520	0.2535	0.0015	0.2273	0.2283	0.0010
5/16—24	0.3125	0.2854	0.3145	0.3160	0.0015	0.2859	0.2869	0.0010
3/8—24	0.3750	0.3479	0.3770	0.3785	0.0015	0.3484	0.3494	0.0010
7/16—20	0.4375	0.4050	0.4395	0.4410	0.0015	0.4055	0.4065	0.0010
1/2—20	0.5000	0.4675	0.5020	0.5035	0.0015	0.4680	0.4690	0.0010
9/16—18	0.5625	0.5264	0.5645	0.5660	0.0015	0.5269	0.5279	0.0010
5/8—18	0.6250	0.5889	0.6270	0.6285	0.0015	0.5894	0.5904	0.0010
11/16—16	0.6875	0.6469	0.6895	0.6910	0.0015	0.6474	0.6484	0.0010
3/4—16	0.7500	0.7094	0.7520	0.7535	0.0015	0.7099	0.7109	0.0010
7/8—14	0.8750	0.8286	0.8775	0.8790	0.0015	0.8291	0.8301	0.0010
7/8—18	0.8750	0.8389	0.8770	0.8785	0.0015	0.8394	0.8404	0.0010
1 —14	1.0000	0.9536	1.0025	1.0040	0.0015	0.9541	0.9551	0.0010
1 1/8—12	1.1250	1.0709	1.1275	1.1290	0.0015	1.0714	1.0729	0.0015
1 1/4—12	1.2500	1.1959	1.2525	1.2540	0.0015	1.1964	1.1979	0.0015
1 3/8—12	1.3750	1.3209	1.3775	1.3790	0.0015	1.3214	1.3229	0.0015
1 1/2—12	1.5000	1.4459	1.5025	1.5040	0.0015	1.4464	1.4479	0.0015

Lead Tolerance—A maximum lead error of plus or minus 0.0005 inch in 1 inch of thread is permitted.

Commercial Tolerances for Machine Screw Taps
(Dimensions in Inches)

Size	Basic		Tap Measurements					
			Outside Diameter			Pitch Diameter		
	Outside Diam.	Pitch Diam.	Minimum	Maximum	Tolerance	Minimum	Maximum	Tolerance
0–80–F	0.060	0.0519	0.0610	0.0625	0.0015	0.0524	0.0534	0.0010
1–56	0.073	0.0614	0.0740	0.0755	0.0015	0.0619	0.0629	0.0010
64–C	0.073	0.0629	0.0740	0.0755	0.0015	0.0634	0.0644	0.0010
72–F	0.073	0.0640	0.0740	0.0755	0.0015	0.0645	0.0655	0.0010
2–56–C	0.086	0.0744	0.0870	0.0885	0.0015	0.0749	0.0759	0.0010
64–F	0.086	0.0759	0.0870	0.0885	0.0015	0.0764	0.0774	0.0010
3–48–C	0.099	0.0855	0.1000	0.1015	0.0015	0.0860	0.0870	0.0010
56–F	0.099	0.0874	0.1000	0.1015	0.0015	0.0879	0.0889	0.0010
4–32	0.112	0.0917	0.1130	0.1150	0.0020	0.0922	0.0937	0.0015
36	0.112	0.0940	0.1130	0.1150	0.0020	0.0945	0.0960	0.0015
40–C	0.112	0.0958	0.1130	0.1150	0.0020	0.0963	0.0978	0.0015
48–F	0.112	0.0985	0.1130	0.1150	0.0020	0.0990	0.1005	0.0015
5–36	0.125	0.1070	0.1260	0.1280	0.0020	0.1075	0.1090	0.0015
40–C	0.125	0.1088	0.1260	0.1280	0.0020	0.1093	0.1108	0.0015
44–F	0.125	0.1102	0.1260	0.1280	0.0020	0.1107	0.1122	0.0015
32–C	0.138	0.1177	0.1390	0.1410	0.0020	0.1182	0.1197	0.0015
36	0.138	0.1200	0.1390	0.1410	0.0020	0.1205	0.1220	0.0015
40–F	0.138	0.1218	0.1390	0.1410	0.0020	0.1223	0.1238	0.0015
7–30	0.151	0.1294	0.1520	0.1540	0.0020	0.1299	0.1314	0.0015
32	0.151	0.1307	0.1520	0.1540	0.0020	0.1312	0.1327	0.0015
36	0.151	0.1330	0.1520	0.1540	0.0020	0.1335	0.1350	0.0015
8–30	0.164	0.1423	0.1650	0.1670	0.0020	0.1428	0.1443	0.0015
32–C	0.164	0.1437	0.1650	0.1670	0.0020	0.1442	0.1457	0.0015
36–F	0.164	0.1460	0.1650	0.1670	0.0020	0.1465	0.1480	0.0015
40	0.164	0.1478	0.1650	0.1670	0.0020	0.1483	0.1498	0.0015
9–24	0.177	0.1499	0.1780	0.1800	0.0020	0.1504	0.1519	0.0015
30	0.177	0.1553	0.1780	0.1800	0.0020	0.1558	0.1573	0.0015
32	0.177	0.1567	0.1780	0.1800	0.0020	0.1572	0.1587	0.0015
10–24–C	0.190	0.1629	0.1910	0.1930	0.0020	0.1634	0.1649	0.0015
28	0.190	0.1668	0.1910	0.1930	0.0020	0.1673	0.1688	0.0015
30	0.190	0.1684	0.1910	0.1930	0.0020	0.1689	0.1704	0.0015
32–F	0.190	0.1697	0.1910	0.1930	0.0020	0.1702	0.1717	0.0015
12–24–C	0.216	0.1889	0.2170	0.2190	0.0020	0.1894	0.1909	0.0015
28–F	0.216	0.1928	0.2170	0.2190	0.0020	0.1933	0.1948	0.0015
32	0.216	0.1957	0.2170	0.2190	0.0020	0.1962	0.1977	0.0015

Lead Tolerance

A maximum lead error of plus or minus 0.003 inch in 1 inch of thread is permitted.

C = coarse thread standard. F = fine thread standard.

CHAMFER ON DIES

All standard dies are chamfered approximately as shown in the following table.

APPROXIMATE NUMBER OF THREADS CHAMFER

Type of Die	Front Face	Rear Face
Spring screw threading	$2\frac{1}{2}$–3	
Solid square bolt	$2\frac{1}{2}$–3	1–$1\frac{1}{2}$
Solid square pipe	$2\frac{1}{2}$–3	0
Adjustable round split, straight thread	$2\frac{1}{2}$–3	1–$1\frac{1}{2}$
Adjustable round split, taper thread	$2\frac{1}{2}$–3	0
Gas fixture	$2\frac{1}{2}$–3	1–$1\frac{1}{2}$
Hexagon rethreading	1	1

Double Depth of Threads

Threads per in.	V Threads D D	U. S. St'd D D	Whit. St'd D D	Threads per in.	V Threads D D	U. S. St'd D D	Whit. St'd D D
2	.86650	.64950	.64000	28	.06185	.04639	.04571
2¼	.77022	.57733	.56888	30	.05773	.04330	.04266
2⅜	.72960	.54694	.53894	32	.05412	.04059	.04000
2½	.69320	.51960	.51200	34	.05097	.03820	.03764
2⅝	.66015	.49485	.48761	36	.04811	.03608	.03555
2¾	.63019	.47236	.46545	38	.04560	.03418	.03368
2⅞	.60278	.45182	.44521	40	.04330	.03247	.03200
3	.57733	.43300	.42666	42	.04126	.03093	.03047
3¼	.53323	.39966	.39384	44	.03936	.02952	.03136
3½	.49485	.37114	.36571	46	.03767	.02823	.02782
4	.43300	.32475	.32000	48	.03608	.02706	.02666
4½	.38488	.28869	.28444	50	.03464	.02598	.02560
5	.34660	.25980	.25600	52	.03332	.02498	.02461
5½	.31490	.23618	.23272	54	.03200	.02405	.02370
6	.28866	.21650	.21333	56	.03093	.02319	.02285
7	.24742	.18557	.18285	58	.02987	.02239	.02206
8	.21650	.16237	.16000	60	.02887	.02165	.02133
9	.19244	.14433	.14222	62	.02795	.02095	.02064
10	.17320	.12990	.12800	64	.02706	.02029	.02000
11	.15745	.11809	.11636	66	.02625	.01968	.01939
11½	.15069	.11295	.11121	68	.02548	.01910	.01882
12	.14433	.10825	.10666	70	.02475	.01855	.01828
13	.13323	.09992	.09846	72	.02407	.01804	.01782
14	.12357	.09278	.09142	74	.02341	.01752	.01729
15	.11555	.08660	.08533	76	.02280	.01714	.01673
16	.10825	.08118	.08000	78	.02221	.01665	.01461
18	.09622	.07216	.07111	80	.02166	.01623	.01600
20	.08660	.06495	.06400	82	.02113	.01584	.01560
22	.07872	.05904	.05818	84	.02063	.01546	.01523
24	.07216	.05412	.05333	86	.02015	.01510	.01476
26	.0661	.04996	.04923	88	.01957	.01476	.01454
27	.06418	.04811	.04740	90	.01925	.01443	.01422

This gives the depth to allow for a full thread in a nut or similar piece of work for threads for 2 to 90 per inch, regardless of the diameter. A special nut for a 2-inch bolt, 20 threads per inch, American Standard would have a hole 2. − .06495 = 1.93505 inches in diameter bored in it.

Elgin Watch Screw Taps

The table below gives all of the standard taps used in connection with the screws listed by the Elgin Watch Co. The diameter in thousandths of an inch and number of threads per inch are marked on the handle of each tap.

Diameter of Tap		Threads per Inch	Diameter of Drill	
Inches	Millimeters		Inches	Millimeters
.0132	.33	360	.0112	.28
.0148	.37	320	.0120	.30
.0168	.42	260	.0132	.33
.0208	.52	220	.0168	.42
.0228	.57	260	.0188	.47
.0248	.62	220	.0200	.50
.0268	.67	180	.0220	.55
.0288	.72	220	.0248	.62
.0308	.77	180	.0248	.62
.0308	.77	220	.0268	.67
.0368	.92	140	.0280	.70
.0368	.92	220	.0268	.67
.0408	1.02	120L	.0300	.75
.0408	1.02	200	.0348	.87
.0428	1.07	120	.0328	.82
.0448	1.12	110	.0340	.85
.0468	1.17	110	.0348	.87
.0488	1.22	140	.0400	1.00
.0488	1.22	200	.0436	1.09
.0508	1.27	110L	.0388	.97
.0548	1.37	180	.0488	1.22
.0608	1.52	110	.0488	1.22
.0608	1.52	110L	.0488	1.22
.0708	1.77	180L	.0648	1.62
.0768	1.92	110L	.0708	1.77
.0772	1.93	80L	.0612	1.53
.0892	2.23	80L	.0712	1.78

Observe that several different numbers of screws are the same as relate to the diameter and number of threads per inch, thus requiring a comparatively small number of taps to embody the entire line. "L" indicates a left-hand thread.

Waltham Watch Screw Taps

This gives the pitch, the diameter of the thread and also th proper size of the tap drill, for all the screws used in the Waltham Watch movements.

No. of Tap	No. of Threads to an Inch	Diameter of Thread on Screws		Diameter of Drill	
		In Inches	In Millimeters	In Inches	In Millimeters
1	110	0.05906	1.50	0.05197	1.32
3	110	0.04724	1.20	0.04016	1.02
5	120	0.04331	1.10	0.03741	0.95
7	140	0.03937	1.00	0.03347	0.85
9	160	0.03661	0.93	0.02796	0.71
11	170	0.05276	1.34	0.04803	1.22
13	180	0.03937	1.00	0.03347	0.85
15	180	0.03268	0.83	0.02796	0.71
17	200	0.02560	0.65	0.02126	0.54
19	220	0.02166	0.55	0.01772	0.45
21	240	0.01772	0.45	0.01339	0.34
23	254	0.01379	0.35	0.01064	0.27

Pendant Taps

Size	Diameter of Tap		Threads per Inch	Diameter of Drill	
	Inches	Millimeters		Inches	Millimeters
18	.236	5.90	50	.211	5.28
16	.200	5.00	60	.180	4.50
12–6	.176	4.40	66	.158	3.95
0	.156	3.90	66	.138	3.45
5/0	.128	3.20	80	.114	2.85
10/0	.103	2.58	90	.086	2.15

Crown Taps

Size	Diameter of Tap		Threads per Inch	Diameter of Drill	
	Inches	Millimeters		Inches	Millimeters
18	.091	2.28	60	.071	1.78
16	.077	1.93	72	.063	1.58
12–6–0	.061	1.53	80	.048	1.20
5/0–10/0	.048	1.20	110	.038	0.95

Watchmakers' Measurements

Showing the comparative values of the standards of measurements commonly used by watchmakers.

One Douzieme	=	.0074 inch
One Millimeter	=	.03937 inch
One Ligne	=	.0888 inch
One Ligne	=	2.256 M. M.

The Elgin Co. have two gages, one known as the "upright," the other as the "fine."

One degree "upright" gage.. = $\frac{1}{500}$ or 0.002 in.
One degree "fine" gage..... = $\frac{1}{2500}$ or 0.0004 in.

Table of Jewel Setting Diameters

Showing their Sizes in Thousandths of an Inch and Equivalent Diameters in Millimeters

Inches	Millimeters	Inches	Millimeters	Inches	Millimeters
.054	1.37	.088	2.23	.126	3.20
.060	1.52	.092	2.33	.140	3.55
.070	1.78	.096	2.43	.144	3.65
.076	1.93	.106	2.69	.156	3.96
.080	2.03	.116	2.94	.160	4.06
.084	2.13	.122	3.09	.170	4.31
.086	2.18				

Thickness of Pallet Stones

In Thousandths of an Inch and Equivalent Thickness in Millimeters

	Inches	Millimeters
18 and 16 Old Style (thick)	.0168	.4267
18 and 16 New Style (thin)	.0148	.3759
6 Old Style (thick)	.0146	.3708
6 New Style (thin)	.0128	.3251

Tapping and Threading Speeds

In multiple machine tapping the Fox Machine Co. recommend 30 feet cutting speed for cast iron and aluminum and about 18 feet for steel. A full thread is unnecessary and requires more space for chips in blind holes.

Threading Pipe

The Bignall & Keeler Manufacturing Co., Edwardsville, Ill., for pipe-threading machines with carbon dies and 13½ to 14 feet for high-speed cutters advocate a cutting speed of 17 to 17½ feet per minute. They advise nothing but lard oil on the dies.

It will be understood in all the cases cited that the figures given are merely a guide as to what can be done and do not record performances in any particular. Soft stock can be run very fast, and hard, gritty stock is very hard on the dies. The only safe rule is to run as fast as possible without undue heating of the taps or dies.

FILES

Files are designated both by the spacing of their teeth and the shape or cross-section of steel on which the teeth are cut, the size always referring to their length, which is measured from the point cutting to the end of the file proper, but the measurement never includes the tang which fits into the handle.

Terms Used

The back of a file is the convex or rounding side of half-round, cabinet and other files having a similar shape.

A file is Bellied when it is full or large in the center.

A Blunt file is the same size its whole length, instead of being tapered.

An Equaling file is one which looks blunt, but which has a slight belly or curve from joint to tang.

A Float file is a coarse single cut made for use on soft metals or wood and frequently used by plumbers.

A Safe-edge is an edge left smooth or blank so that the file will not cut if it strikes against the side of a slot or similar work.

The Tang is the small pointed end forged down for fitting into the handle.

Three square files are double cut and have teeth only on the sides, while taper saw files are usually single cut and have teeth on the edge as well as the sides. This makes the taper saw files broad on the edge or without sharp corners, while the three square files have very sharp corners.

A special-angle tooth file is made for brass work. The first cut is square across the file, while the second is at quite an acute angle, about 60 degrees from the first cut.

Doctor files are very similar to these except that the first cut is about 15 degrees instead of being square across the file.

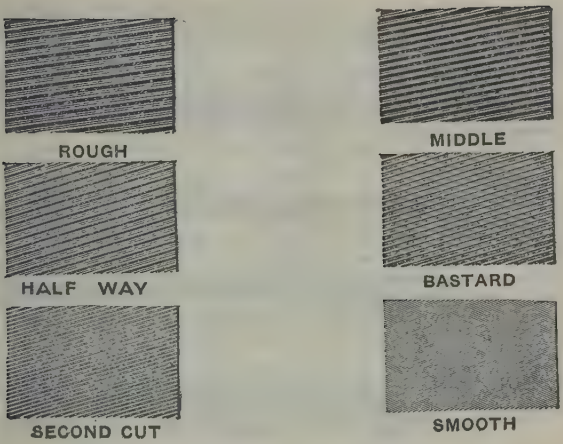
A lock file has safe edge and the teeth only go about one-third the way across from each side, leaving the center blank. The teeth are single cut.

Height of Work

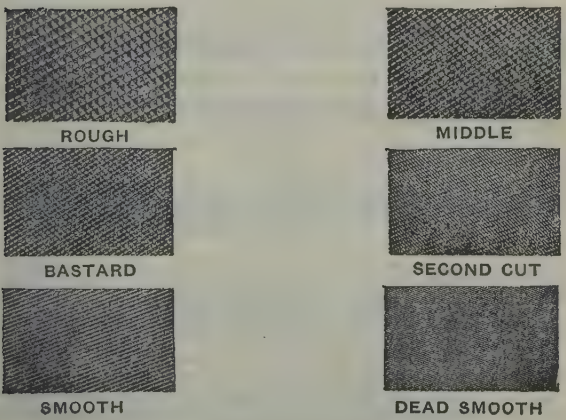
The work should be at a convenient height, which will usually vary from 40 to 44 inches for most men, with an average of 42 inches. This means the height of the work, not the bench.

Pickling Bath

A good pickle to soften and loosen the scale on cast iron before filing is made of from four to ten parts of water to one part of sulphuric acid. A too strong solution will not act so rapidly as one sufficiently diluted. Other acids are also used. The pickle is usually kept in a lead-lined tank.



Actual Tooth Spacing of Single Cut Files



Actual Tooth Spacing of Double Cut Files

For brass castings use a pickle of five parts water to one part nitric acid. This is particularly good if they are to be lacquered afterwards.

The usual way to use the pickle is to place the castings on a sloping platform which drains into the tank, and pour the pickle over them. After the acid gets in its work the castings are washed in water and rattled (or rumbled), scraped or otherwise cleaned. Sometimes the castings are dipped into the acid tanks.

The Teeth of Files

The cut of a file or the number of teeth per inch vary with the length of the file itself and the kind of a file, and is a little confusing, as a rough cut in a small file may be as fine as a second cut of a larger size. The cuts used on regular 12-inch files are shown in the illustration and represent the practice of Henry Disston & Sons. The same makers also supply the table of cuts per inch used on their machines, which are as follows:

Regular Taper Files

Length, inches—2½, 3, 3½, 4, 4½, 5, 5½, 6, 6½, 7, 8, 9, 10.
Teeth per inch—64, 56, 52, 50, 48, 46, 44, 42, 42, 40, 38, 36, 34.
Slim Tapers— 64, 64, 60, 58, 56, 52, 50, 50, 46, 46, 44, 40, 38.

Mill File, Bastard Cut

Length—4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20 in.
Teeth—56, 50, 48, 46, 44, 42, 40, 38, 36, 34, 32, 30, 28, 26, 24, 22 per inch.

Flat File, Bastard Cut

48, 42, 38, 36, 32, 30, 26, 24, 22, 20, 20, 18, 18, 16, 16, 14.

Single cut files usually have teeth at about 25 degrees and in double cut files the other cut is usually from 45 to 50 degrees. Fine machinists files are made in ten numbers from 00 to 8.

The Shapes of Files

In the following pages the shapes of standard files are shown. The names are as follows:

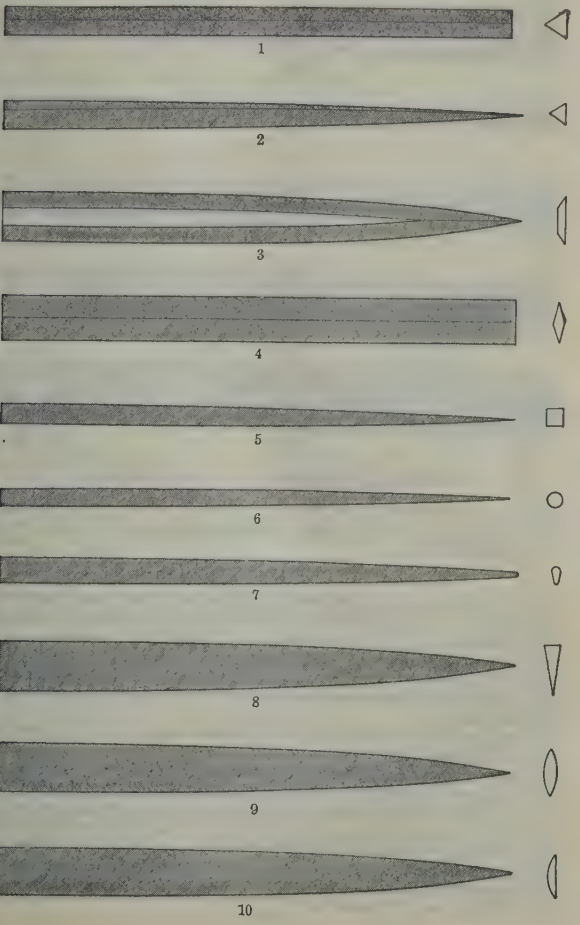
1. Metal saw—blunt.
2. Three-square or triangular.
3. Barrette.
4. Slitting.
5. Square.
6. Round or rat-tail.
7. Pippin.
8. Knife.
9. Crossing.
10. Half-round.
11. Crochet.
12. Warding.
13. Extra narrow pillar.
14. Narrow pillar.
15. Pillar.
16. Hand.

Files are cut in two ways, single and double. The first has but a single line of cuts across the surface, at an angle with the file body but parallel to each other. The double-cut file has two lines of cuts, at an angle with each other, and the second cut being usually finer than the first. Some prefer the single cut, for filing in the lathe. Rasps have single teeth forced up with a punch.

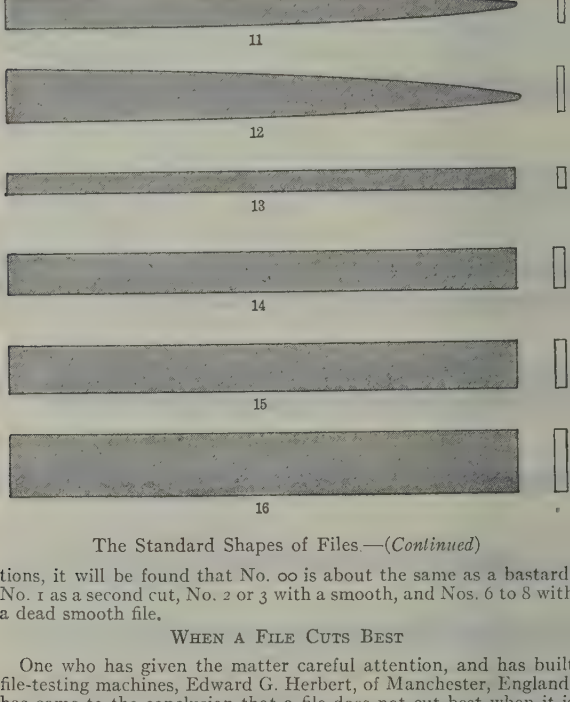
The old method of designating the cuts were rough, coarse, bastard, second cut, smooth and dead smooth. Some makers are now using a series of numbers—usually eight to ten—instead of the six designations by name formerly employed. The uses of the

various cuts depend on the shop in question and must be learned from observation and experience in each case.

The grades of cut used by them run from No. 00 to No. 8, and while it is hard to exactly compare them with the old-style designa-



The Standard Shapes of Files



The Standard Shapes of Files.—(*Continued*)

tions, it will be found that No. 00 is about the same as a bastard, No. 1 as a second cut, No. 2 or 3 with a smooth, and Nos. 6 to 8 with a dead smooth file.

When a File Cuts Best

One who has given the matter careful attention, and has built file-testing machines, Edward G. Herbert, of Manchester, England, has come to the conclusion that a file does not cut best when it is new but after it has been used for some little time, say 2500 strokes or the filing away of one cubic inch of metal. Another curious feature is that its usefulness seems to come to a sudden instead of a gradual end.

A bastard file having 25 teeth to the inch, operating on a surface one inch square with a pressure of 30 pounds, which is about equal to heavy hand filing, gives 25 cutting edges about one inch long, which likens it somewhat to a broad cutting tool in a planer.

In cutting a file the metal is forced up in a sort of a bur, and occasionally the top of the tooth slopes over backward which is the reason that a file often cuts better after these are broken or worn off. Then, too, when a file is new all the teeth are not of the same height and only a few points cut. As they wear down more teeth come into contact and do more work.

WORK BENCHES

The duties of a bench vary with the shop, according to the work that is to be done on it or at it. If it is simply a filing bench, the main requirement is that it support a vise firmly and at the proper height. If an assembling bench, these are not the important features, and just what it needs depends on the kind of work being handled.

For the average shop work we want a bench that is rigid; that will stand chipping and filing; that can be used in testing work on a surface plate or in handling jigs and fixtures; that will not splinter badly or otherwise injure a tool should it happen to drop on it. For the toolmaker the cast-iron bench top has some advantages, but both the bench and the tool are very liable to be marred if a tool is dropped on such a bench, so for general use we rely on wood. The bench should be set out from the wall to allow the

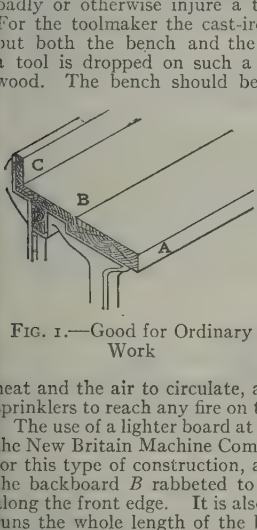


Fig. 1.—Good for Ordinary Work

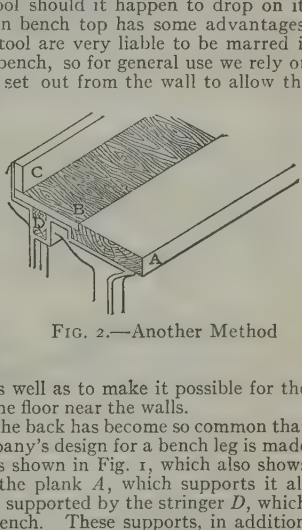


Fig. 2.—Another Method

heat and the air to circulate, as well as to make it possible for the sprinklers to reach any fire on the floor near the walls.

The use of a lighter board at the back has become so common that the New Britain Machine Company's design for a bench leg is made for this type of construction, as shown in Fig. 1, which also shows the backboard *B* rabbeted to the plank *A*, which supports it all along the front edge. It is also supported by the stringer *D*, which runs the whole length of the bench. These supports, in addition to the cross bearing of the legs every 6 or 8 feet, give the backboard a stiffness that is unknown where they are simply laid flush and not rabbeted and the stringer is absent.

All cracks are more or less of a nuisance in bench work, but in this case any shrinkage can be taken up by wedging against the iron support of the board *C* and the edge of the backboard *B*.

Another style bench with this same leg is shown in Fig. 2. Here the front plank *A* and the backboard *C* are the same as before, but

instead of having one backboard, this part of the bench is made up of narrow strips as *B*, fitting into rabbet in plank *A* and supported by the stringer *D* as before. These narrow boards can be either tongued and grooved hardwood flooring, or can be square edges, as preferred; in either case any shrinkage can be taken up by forcing the boards together.

A cheaper form of bench is shown in Fig. 3, where the heavy planking is entirely dispensed with and the boards *B* run the full



FIG. 3.—A Cheaper Way

width of the bench as shown. Running along the front, underneath the main boards, is a soft plank *A* which supports the edge of the bench where the most work comes, and under the back is the 2- by 6-inch stringer as before. Here, too, the boards can be either notched or square edge. The objection raised against the tongue and groove is that the edges are apt to split off if heavy articles are dropped on them. An advantage claimed for the boards running this way is that work going on or off the bench is always in the direction of

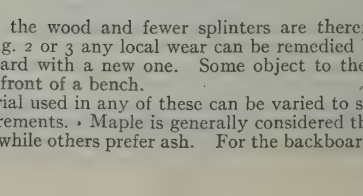


FIG. 4.—Steel Bench Leg

the grain of the wood and fewer splinters are therefore formed. In either Fig. 2 or 3 any local wear can be remedied by replacing the worn board with a new one. Some object to the end of the grain at the front of a bench.

The material used in any of these can be varied to suit the individual requirements. Maple is generally considered the best wood for a bench, while others prefer ash. For the backboards hard pine

is often used and even cheaper woods will answer if necessary, although it probably pays to use maple all through if it can be afforded.

Pressed-steel legs are now used extensively. Fig. 4 shows one made by the New Britain Company. Oval bolt holes allow for the shrinkage of the wooden top. Bolts must start at front of slot so that shrinkage can be taken up. The first plank is 12 to 14 inches wide and $2\frac{3}{4}$ or 3 inches thick. It can be had in 16-foot lengths, so joint will come on every other leg.

Benches are also occasionally built up from small blocks so as to present an end grain on the top, the same as butchers' blocks. Others glue up strips on edge and plane down to a smooth surface so as to do away with all cracks. Zinc or even heavy paper covers are often used where fine work is being assembled to prevent its finding its way into cracks and crevices. Battleship linoleum makes a fine covering for benches used in assembling small parts. It has a yielding surface and yet lasts a long time.

The usual work bench is from 33 to 35 inches from the floor to the top, about 29 or 30 inches wide, and has the front plank 3 inches with backboards 1 inch thick. A cast-iron leg of this type weighs about 50 pounds. Pressed steel legs are considerably lighter.

BRAZING, SOLDERING AND WELDING

Almost everyone thinks he can solder, yet if we examine the work carefully we will find that only about 10 per cent of the work is really done as it should be. Thorough soldering is frequently referred to as sweating, and it is remarkable the difference in strength between a well-fitted and "sweated" junction of the metals and one as ordinarily soldered.

A point frequently overlooked is the important one of properly cleaning the surfaces to be joined. This is too often left for the flux to correct. Another neglected point is the selection of the flux to be used, although nearly all of the metals can be joined by the use of the same flux. The after effects resulting from improper cleaning after soldering are frequently worse than the good effect of the soldering. This is particularly noticeable in electrical work.

For strength, fit the parts accurately. The more accurate the fitting the stronger the result. Use a solder with as high a melting point as possible. Apply the proper heat. The nearer the temperature of work to be joined is brought to the fusing point of the solder the better will be the union, since the solder will flow more readily.

Fluxes for Different Metals

There are on the market a number of fluxes or soldering salts that are giving good satisfaction. A form that is non-corrosive and very popular with electrical workers is the soldering stick in which the ingredients are molded into stick form.

A flux in soldering removes and prevents the formation of an oxide during the operation of soldering, and allows the solder to flow readily and to unite more firmly with the surfaces to be joined.

For sheet tin, on the best work rosin or colophony is used; but owing to the ease of applying and rapidity of working, zinc chloride or acid is more generally used. Beeswax can also be used, as also almost any of the pastes, fats or liquids prepared for the purpose.

For lead, a flux of oil and rosin in equal parts works very well. Tallow is also a good flux. Rosin or colophony is much used, and zinc chloride will keep the surfaces in good condition.

Lead burning is a different operation from soldering, and at the present time almost a lost art. The surfaces must be bright and free from oxide; solder is not used as a flux, but a piece of lead and rosin or oil.

For brass, zinc chloride or almost any of the soldering preparations is used. Care must be taken to remove any scale or oxide if a good joint is wanted. On new metal this is not much trouble, but on old or repair work it is sometimes exceedingly difficult. This is particularly noticeable on metal patterns that have been in use for some time. The scraper must be brought into use to remove it. Many use with considerable success an acid dip such as is com-

monly used by electro platers, for removing the oxide. Oily or greasy work can be cleaned by the use of potash or lye, but care must be exercised that the brass is not left too long in the solution, especially if it contains any joints previously soldered, since the action set up will dissolve the solder entirely or roughen up the joint to such an extent as to require refinishing.

For copper, the same fluxes as for brass are used. On old work it is almost always necessary to scrape the parts to be joined to get the solder to hold. A particularly difficult piece of work to solder is an old bath tub. The grease and soap form a layer that is impervious to any of the fluxes, and it must be carefully removed entirely if good work is wanted.

For zinc, use muriatic acid almost full strength or chloride of zinc solution. Zinc is the metal that has a "critical temperature" more than any other metal except the softer alloys. If the iron is overheated, the zinc is melted and a hole burned in the metal; even if this does not occur, the surface of the metal is roughened and there is formed on the soldering copper an alloy that will not flow but simply makes a pasty mass. At the correct heat the solder will flow readily and unite firmly with the metal. Especially if the work is to be painted, care should be taken to neutralize and wash off any excess of acid or soldering solution, as it is impossible to cause paint to adhere properly unless this is done.

For galvanized iron, use muriatic acid, chloride of zinc solution or rosin, and be sure to see that the acid is neutralized if the work is to be painted. Many cornices and fronts are made of this metal and are very unsightly in a short time after being painted, particularly at the joints, owing to lack of care in removing the excess flux.

An action that is not usually taken into consideration in the joining of galvanized iron or zinc with copper, as is sometimes done, is the electrical action set up by the metals if any moisture is present. This is very noticeable in cities where the acid from the atmosphere assists in the action. It will nearly always be found that the zinc or galvanized iron has been greatly injured at the places joined.

For wrought iron or steel, zinc chloride is best. The iron or steel, to make good work, should be previously freed from scale or oxide and tinned before joining. Where the oxide is not very heavy, the iron can be cleaned by brushing with muriatic acid and rubbing with a piece of zinc.

The Fluxes Themselves

The above paragraphs give the fluxes adapted to the various metals; the fluxes themselves are as follows:

Hydrochloric or muriatic acid. The ordinary commercial acid is much used in full strength or slightly diluted to solder zinc, particularly where the zinc is old or covered with an oxide.

Rosin or colophony, powdered, is commonly used for copper, tin and lead, and very generally by canneries and packing houses on account of its non-poisonous qualities. It is also used mixed with common olive oil. Turpentine can also be used as a flux. Beeswax is a good but expensive flux. Tallow is also used for lead pipe, but is more frequently mixed with rosin.

Palm or cocoa oil will work well, but is more generally used in the manufacture of tin plate. The common green olive oil works very well with the more fusible solders.

As expedients we can use a piece of common stearine candle or a piece of common brown rosin soap or cheap furniture varnish, which is largely composed of rosin. Paraffin, vaseline and stearine are recommended for use with some of the alloys for soldering aluminum.

Chloride of zinc, acid, or soldering liquid, is the most commonly used of all the fluxes; as usually prepared, simply dissolve as much scrap zinc in the ordinary commercial muriatic acid as it will take up. But if it is diluted with an equal quantity of water and a small quantity of sal ammoniac is added it works much better and is less likely to rust the articles soldered. If they are of iron or steel, about 2 ounces to the pint of solution is about the proper quantity of powdered sal ammoniac to add.

In preparing this solution, a glass or porcelain vessel should be used; owing to the corrosive fumes, it should be done in a well-ventilated place. Use a vessel of ample capacity, since there is considerable foaming or boiling of the mixture.

Soldering liquid, non-corrosive, is also prepared by dissolving the zinc in the acid as above and adding one fourth of the quantity of aqua ammonia to neutralize the acid, then diluting with an equal quantity of water.

Soldering liquid, neither corrosive nor poisonous. Dissolve 1½ parts glycerin, 12 parts water, and add 1½ parts lactic acid.

Soldering paste. When a solution of chloride is mixed with starch paste, a syrupy liquid is formed which makes a flux for soldering.

Soldering fat or paste. Melt 1 pound of tallow and add 1 pound of common olive oil. Stir in 8 ounces of powdered rosin; let this boil up and when partially cool, add with constant stirring, ¼ pint of water that has been saturated with powdered sal ammoniac. Stir constantly until cool. By adding more rosin to make it harder, this can be formed into sticks. A very good acid mixture for cleaning work to be soldered is equal parts of nitric and sulphuric acid and water. *Never pour the water into the acid.*

Cleaning and Holding Work

For copper work a dilute sulphuric acid is best. Articles of lead and zinc can be cleaned with a potash solution, but care must be exercised as the alkalies attack these metals. For zinc, a dilute solution of sulphuric or muriatic acid will clean the surface.

For cleaning or removing the oxide or other foreign material, scrapers and files are frequently used. An old file bent at the ends and with the corners flaring makes a handy tool. Grind the edge sharp and make as hard as possible.

To enable difficult points to be "filled," sometimes a small piece of moist clay pressed into shape to form the desired shape can be used to advantage as a guide for the solder. Another use of the clay is to embed the parts in, to hold them in position for soldering.

Plaster of paris is also used for this purpose, but is sometimes difficult to remove, especially in hollow pieces. A dilute solution of muriatic acid will help to get this out, however.

Castings containing aluminum are always harder to solder than other alloys. In some instances where the percentage of aluminum is high, it is necessary to copperplate the parts to be joined before a satisfactory joint can be made. In nearly every instance the work can be "stuck" together, but not actually soldered.

In metal-pattern making too little attention is given to both the fitting of the parts and the selection of the solder to joint the work. A good grade should always be used, and it must be borne in mind that the higher the melting point of the solder the stronger the joint.

A very good job of soldering can be done on work that will permit of it by carefully fitting the parts, laying a piece of tin foil, covered on both sides with a flux, between the parts to be joined and pressing them tightly together. Heat until the foil is melted. This is very good in joining broken parts of brass and bronze work. If they fit well together, they can frequently be joined in this manner so that the joint is very strong and almost imperceptible.

Soldering Cast Iron

For cast iron, the flux is usually regarded as a secret. A number of methods are in use; one of the oldest and least satisfactory is to brush the surfaces thoroughly with a brass scratch brush. Brush until the surface is coated with brass, then tin this surface and solder as usual. If plating facilities are to be had, copperplate the parts and solder together. This method has been used very successfully for a number of years.

A fair substitute for the above is to clean the surfaces thoroughly and copperplate them with a solution of sulphate of copper: about 1 ounce sulphate of copper, ½ pint water, ½ ounce sulphuric acid. Brush this solution on or dip into the solution, rinse off and dry it well before soldering.

Another method is to tin the cast iron. To do this, first remove all scale until the surface is clean and bright. The easiest way to do this is with the emery wheel. Dip in a lye to remove any grease, and rinse the lye off; then dip into muriatic acid of the usual strength. Then go over the surface with rosin and a half and half solder. It may be necessary to dip into the acid several times to get the piece thoroughly tinned. Rubbing the surface of the iron with a piece of zinc while the acid is still on it will facilitate the tinning.

Another method of soldering cast iron is to clean the surface as in the previous operation and then brush over with chloride of zinc solution and sprinkle powdered sal ammoniac on it; then heat until the sal ammoniac smokes. Dip into melted tin and remove the surplus; repeat if not thoroughly tinned. Half tin and half lead works well as a solder for this.

Commutator wires and electrical connections should never be soldered by using an acid solution, owing to the corrosive action afterward. A good flux is an alcoholic solution of rosin.

Solders and Fusible Alloys

Solders act under constant stress considerably like plastic or semi-fluid material. Their fluidity resembles that of tar or gum, and their distortion with time is greater than would be thought. In a series of tests a notable point brought out was the varying degrees of strength with age. Tensile strength increases with the percentage of tin present, but when the solder's age is increased as a factor, the product possesses its maximum value at 60 per cent. tin, showing this property as similar to that of the melting point and depending upon chemical composition.

For general work, the solder requiring resistance to stress is 60 per cent. tin, but for work requiring little mechanical strength, such as sealing, a lower per cent. of tin may be used.

Generally speaking, all solders are alloys of lead and tin. The more lead the alloy contains, above 40 per cent., the higher is its melting point, as also the less lead it contains, below 40 per cent., the lower is its melting point.

Nearly all aluminum solders are alloys of tin and aluminum that contain from 15 to 25 per cent. aluminum. A small per cent. of copper or nickel, never exceeding 2 or 3 per cent., is sometimes used. The exact point of separation between a fusible metal and a non-fusible one is very uncertain, thus several additional alloys are given in the table. In filling up imperfections in ornamental castings for plugs in electrical wiring and on boilers in engineering work, fusible alloys are used. Sometimes defects in structural steel have been filled in with expanding alloy, and then coveredwith a coat of paint. The United States Government rules call for pure Banca tin for boiler plugs, but this is not essential and any good tin will serve the purpose.

Experiments have been made in an engineering college quite recently for the purpose of finding the way of making solder joints, as well as measuring their tensile strength. Any pressure upon the solder at the moment of setting diminishes the strength of the joint. Thus, in making a solder joint, the upper piece should be held above the lower one, the solder fused by means of two blow torches, and the pieces brought together by very slow and easy pressure. By employing this method, which differs from that commonly called "sweating," the joint is less liable to be broken, as the crystalline composition of the resulting mass contains less resistance at this time.

In addition it is found that there is remarkable variation with time of the tensile strength of such joints, which is also in accord with what would be considered proper by engineering science in this field. Under any circumstances the average strength attained does not exceed 27,000 pounds per square inch, and was obtained from solder made with three-fifths of its composition tin.

The melting point of alloys which fuse at a low temperature may be found by tying a small wire around a fragment of alloy and hanging it in a bath of water. A thermometer should be kept in the bath and the temperature increased slowly until the alloy melts. The melting point of the alloy can then be noted by the temperature of

TABLE SHOWING MELTING POINTS OF SOLDER METAL AMERICAN SOCIETY FOR TESTING MATERIALS

Grade	Formula, Per Cent			Melting Point	
	Tin	Lead	Antimony	Degrees Centigrade	Degrees Fahrenheit
Tin	100.00			232	449.6
0 A	63.00	37.00	0.12	181	357.8
1 A	50.00	50.00	0.12	181	357.8
1 B	49.25	50.00	0.75	185	365.0
2 A	45.00	55.00	0.12	181	357.8
2 B	43.50	55.00	1.50	188	370.4
3 A	40.00	50.00	0.12	181	357.8
3 B	38.00	60.00	2.00	188	370.4
4 A	37.50	62.50	0.12	181	357.8
4 B	35.50	62.50	2.00	188	370.4
5 A	33.00	67.00	0.12	181	357.8
5 B	31.00	67.00	2.00	188	370.4
Lead		100.00		327	620.6

Class A solders are made from new metal only. Class B from at least one-half new metal. For galvanized iron and zinc only Class A should be used. Grade 4 is suitable for wipe joints.

COMPOSITION AND MELTING POINT OF FUSIBLE ALLOYS

Alloy	Lead	Tin	Bismuth	Other Constituents	Melting Point	
					Cent.	Fahr.
1. Steam-boiler plug	48.4		12.8	38.8	171	340
2. Steam-boiler plug	44.5		22.2	33.3	141	285
3. Steam-boiler plug	42.1		42.1	15.8	123	253
4. Steam-boiler plug	10.0	40.0	50.0		116	240
Sir Isaac Newton's	30.0	20.0	50.0		100	212
Suitable for casts	31.25	18.75	50.0		98	208
Rose's alloy	28.1	21.9	50.0		95	203
D'Arcet's alloy	25.0	25.0	50.0	Cadmium	93	200
Wood's alloy	25.0	12.5	50.0	12.5	60	140
Lipowitz's alloy	26.9	12.7	50.0	10.4	66	150
Expanding alloy	66.7		8.3	25.0	66	150

the bath. For higher temperature a bath of paraffin or oil is used. If bismuth is added to these alloys the melting point is lower, as bismuth possesses the quality of expanding on cooling, a property which is very unusual in metals. Bismuth is used not only to make the alloy or solder more easily worked, by diminishing its melting point, but if sufficient quantity be present its expansive tendency counterbalances the effects of the contraction of the other metals, and the total result is the prevention or reduction of shrinkage in the mold. The addition of cadmium still farther lowers the melting point of such alloys as those of bismuth, lead and tin, which in themselves have very low melting points.

It is recommended that the grade of solder metal be selected which contains the least amount of tin required to give suitable flowing and adhesive qualities for the work in hand.

Brazing or Hard Soldering

The main difference between soldering and brazing is in the kind of metal used in making the joint and in the temperature required to melt it. Brazing is done with a torch, in a fire or by dipping the joint to be brazed into the molten metal used for making the joint. This is called "dip" brazing.

Hard solders contain more or less copper and are frequently referred to as spelter. A substantial solder contains 60 per cent copper, 20 per cent tin and 20 per cent zinc. An easily melted yellow, hard solder contains about 45 per cent copper and 55 per cent zinc. This solder is really a brass, but at times is used for soldering, binding and filling purposes.

Tests made by F. Grotts, chief metallurgist of the Curtis Aeroplane & Motor Co. in 1918, gave valuable information on brazing. A copper-zinc alloy (4 parts copper to 1 part zinc) gave a strength of 31,200 to 39,800 pounds per square inch. An alloy of 83 per cent copper, 17 per cent zinc gave joints somewhat stronger. With a flux of boric acid, brazing is easy and satisfactory.

Joints brazed with copper-zinc alloys and boric acid in a gas fire nearly all exceeded the maximum strength of the cold-drawn steel used in the tests.

The oxyacetylene torch, however, gave stronger joint than dip brazing or the gas fire, the strength being in the order named.

Heat treating by heating to 1600 degrees Fahr., quenching in oil and reheating to 900 degrees increased the strength of the brazed joint an average of 23 per cent.

Un-treated brazed joints were 19.2 per cent stronger than untreated welded joints. Treated brazed joints were 55 per cent stronger than untreated welded joints. The treated welded joint was 42 per cent stronger than the untreated joint.

OXYACETYLENE WELDING AND CUTTING

Oxyacetylene welding and cutting has made a place for itself in almost every metal-working industry. A welding blow pipe mixes oxygen and acetylene gas in the proper proportions to produce a

neutral flame, that is, a flame with no excess of either gas. It is the hottest flame known. Applied to the edges of two pieces of metal the concentrated heat melts or fuses the metals together. This is called autogenous welding.

One great advantage of this process is that all commercial metals can be welded. When the joint is to be made in a metal more than $\frac{3}{16}$ inches thick, the edges should be beveled so that the welding can begin at the bottom and build up. The bevel is usually about 90-degrees included angle, and is filled gradually with metal from the sides as well as from the welding rod used.

The heat generated by the welding naturally causes expansion that must be considered and provided for, otherwise the contraction due to cooling may cause trouble. Castings are frequently preheated with charcoal, both because it is cheap and because it heats slowly. In some cases, such as locomotive frames, gas torches are sometimes used for preheating. The effect of the welding flame on the work can be varied by moving it to or from the work and also playing it around on the metal.

The welding rod used should be carefully selected for the work. In welding some metals, the proper rod will supply the alloys burnt out by the intense heat of the welding flame. Attention should also be paid to securing the proper flux for the metal being welded. Generally speaking, there are three kinds of fluxes; for cast iron, for aluminum and one for brasses and bronzes. The flux is used to float the oxides out of the weld. Some welders of aluminum do this with a steel rod flattened at one end, to stir or puddle the oxide and scrape it off the surface of the weld.

In some work where extreme heat is not required, either city or natural gas is used with oxygen, instead of acetylene. This combination is useful in lead storage battery work, soft soldering, silver soldering and light brazing. The use of city or natural gas requires a larger tip than where acetylene is used.

Welding and cutting can both be done mechanically in machines having either hand or automatic feed. In such work a lower pressure is generally used.

Blow-pipe tips should be cleaned with a soft brass or copper wire.

There should be a fire-resisting wall between stored tanks of oxygen and oxyacetylene, whether the cylinders be full or empty.

Close values on all cylinders except when they are in use, even if they are empty.

If flame backfires, first, shut off blow-pipe oxygen valve, then the acetylene valve.

It is usual practice to use *black* hose for acetylene and *red* hose for oxygen.

The following tables, from the Oxweld Company, on welding and cutting contain much useful information.

Oxweld Welding Table
Jan. 1, 1925

Thickness of Metal		Size of Welding Head or Tip		Oxygen Pressure, Pounds per Square Inch	*Speed Range, Linear Feet per Hour	Gas Consumption		Iron Welding Rod, Pounds per Linear Foot
Inches	Gage	W-1	W-14 W-9			Oxygen, Cubic Feet per Hour	Acetylene, Cubic Feet per Hour	
	32		0	9	32 –36	0.8	0.7	
	28		1	9	26 –30	1.5	1.4	
1/16	22	2	2	10	22 –26	4.5	4.2	
1/8	16	3	3	10	17 –21	6.6	6.2	0.01
3/16	13	4	4	11	14 –17	8.7	8.3	0.02
1/4	11	5	5	12	11½–14	10.8	10.2	0.04
5/16		6	6	14	9 –11	15.0	14.2	0.08
3/8		7	7	16	7 –9	19.2	18.3	0.15
7/16		8		19	4½–6½	27.6	26.3	0.3
1/2		10		21	3 –4½	36.0	34.3	0.6
3/4		12		25	1½–2½	52.8	50.4	1.4
1		15		30	1 –2	69.7	66.3	2.4

* Lowest speeds are for inexperienced operators and short welds. Highest speeds are for thoroughly experienced operators and long welds.

Oxweld Cutting Table
Jan. 1, 1925

Thickness of Metal, Inches	Size of Cutting Nozzle	Oxygen Pressure, Pounds per Square Inch	Speed Range*		Gas Consumption		Cost per Hour Labor at $0.60 Oxygen at $0.015	
			Machine Cutting, Linear Feet per Hour	Hand Cutting, Linear Feet per Hour	Oxygen, Cubic Feet per Hour	Acetylene, Cubic Feet per Hour	Generator Acetylene at $0.015	Dissolved Acetylene at $0.025
1/4	No. 1	20	107–140	90–139	51	17	1.62	1.79
3/8		25	98–140	100–151	108	20	2.52	2.72
1/2		30	89–130	85–130	126	22	2.82	3.04
3/4	No. 2	35	78–110	65– 95	145	23	3.12	3.35
1		40	64– 95	50– 71	158	24	3.33	3.57
1½		45	38– 60	34– 45	175	25	3.60	3.95
2		45	44– 60	33– 46	248	33	4.82	5.15
3	No. 3	55	37– 51	25– 36	295	39	5.61	6.00
4		65	30– 43	18– 27	339	42	6.32	6.74
5		75	22½– 35	12– 19	382	45	7.00	7.46
6		75	26– 34	17– 27	542	47	9.62	10.11
8	No. 4	95	21–27½	11– 19	655	56	11.27	11.83
10		115	17½–20½	8– 15	787	63	13.35	13.98
12		140	13½–14½	6– 13	949	70	15.89	16 59

* Lowest speeds and highest costs are for inexperienced operators, shor cuts, dirty or poor materials. Highest speeds and lowest costs are fc thoroughly experienced operators, long cuts, clean and good material.

THE WELDING RODS

Great improvements have been made in welding rods and rods can now be secured that melt and flow freely and unite readily with the base metal. They should not only produce clean and sound welds, but also allow the weld to be machined if necessary. Welding rods should be well cared for and not allowed to rust, as this affects the weld. Rods of different sizes are recommended for metal of varying thickness, the following table being suggested by the Oxweld Company.

WELDING ROD—KINDS, SIZES AND FLUXES
SUGGESTED BY THE OXWELD ACETYLENE CO.

Material to Weld	Rod to Use	Diam. of Rod, in Inches	For Metal in Inches
Gray-iron castings.	No. 9 cast alloy rods Ferro flux	1/16 1/8 5/32 3/16	Up to 1/4 1/4–5/16 5/16–1/2 Over 1/2
Steel plates, sheets, pipes, shapes, etc.	No. 7 drawn iron rods copper coated	1/16 5/32 1/8 3/16 1/4	Up to 1/8 1/8–1/4 1/4–1/2 1/2–3/4 Over 3/4
Steel castings	No. 1 mild-steel rods	1/4 3/8	Up to 1/2 Over 1/2
Nickel or chrome steel	No. 3 nickel-steel rods	1/8 1/4 3/8	Up to 1/4 1/4–1/2 Over 1/2
High-carbon steel.....	No. 2 high-carbon rods	1/16 1/8 1/4 3/8	Up to 1/4 1/4–1 Over 1
Brass, Tobin bronze, sheet	No. 10 drawn Tobin bronze rods	1/8 3/16 1/4	Up to 1/4 1/4–3/4 Over 3/4
Brass, bronze, copper, malleable iron	No. 18 drawn Brazo bronze rod	1/4	1/4 or over
Malleable, brass and bronze castings	No. 11 drawn manganese bronze Brazo flux	1/8 3/16 1/4	Up to 1/4 1/4–3/4 Over 3/4
Brass, sheet or cast	No. 13 drawn brass Brazo flux	1/8 3/16 1/4	Up to 1/4 1/4–3/4 Over 3/4
Copper—sheet or cast	No. 12 drawn copper Brazo flux	1/8 3/16 1/4	Up to 1/4 1/4–3/4 Over 3/4
Aluminum sheet	No. 14 drawn aluminum rod—sheet alum. flux	1/8 1/4	Up to 1/4 Over 1/4
Aluminum—cast	No. 15 lignite rod, cast alum. flux	3/16 1/4	Up to 1/8 Over 1/8

CUTTING METALS WITH OXYACETYLENE

The theory of cutting metal with oxyacetylene is very simple. After a small spot of metal has been heated red hot by the combined flame, a jet of oxygen is directed against this spot. The iron and oxygen combine to form an iron oxide and burn a narrow slit in the steel. It is not mere melting, but a chemical process, being in reality an extremely rapid form of the rusting action. The oxygen jet must be maintained under sufficient pressure to blow away the oxide as fast as it is formed.

The torch for cutting has a number of jets, part of which heat the metal red hot and the others supply only oxygen for maintaining combustion and blowing the oxide out of the way. Steel, wrought iron and cast iron of almost any thickness can be cut, from sheet metal to billets 4 feet thick. Boiler plate ¼ inch thick can be cut at the rate of 80 feet per hour and 8-inch armor plate can be cut at 17 feet per hour. Beginners in the use of any new apparatus should pay careful attention to the directions supplied by the maker.

ELECTRIC WELDING

Resistance (incandescent) welding occurs where a low-voltage current is passed from one surface to the other and fuses the two metals together. This has been done for many years. Almost any two metals may be welded by clamping them so as to regulate the heat to the melting point of the metal.

Spot welding passes the current through the plates to be welded by using an electrode on each side of the plate. This method fuses, or welds the two sheets together between points of contact. Both resistance and spot welding are widely used in manufacturing.

Arc welding was a later development and is used in much the same way as the oxyacetylene torch. Direct current is used and the piece to be welded is usually made the positive terminal. The welding rod, or carbon, as the case may be, is the negative. Touching the work with the rod and withdrawing it slightly, draws an arc between them, and the intense heat soon brings the work to the welding temperature.

ARC WELDING AND CUTTING

Arc welding uses from 20 to 75 volts. The amperage depends on the work. With the carbon arc a voltage of 40 and a current from 25 to 600 amperes are common. With the metallic arc the voltage may be 20 to 30, with an amperage of 50 to 300. For cutting, amperage runs up to 1,250, but in general, the current will run about as follows:

CURRENT FOR WELDING WITH METALLIC ELECTRODE

Light work, 25 to 125 amperes; heavy work, up to 250 amperes

Diameter of Electrode in Inches	Amperes Used in Hand Welding	Thickness of Plate to be Welded in Inches
$\frac{1}{16}$	50–75	Up to $\frac{3}{16}$
$\frac{3}{32}$	60–100	Up to $\frac{1}{4}$
$\frac{1}{8}$	80–150	$\frac{1}{8}$ up
$\frac{5}{32}$	125–200	$\frac{1}{2}$ up
$\frac{3}{16}$	175–225	$\frac{5}{8}$ up
$\frac{1}{4}$	200–250	$\frac{3}{4}$ up

For building up metal with a carbon arc on flat surfaces where the work is accessible and conditions favorable, the following is given, for continuous work. On short jobs of 10 minutes or less, the rate may be doubled.

RATE OF DEPOSITING METAL

Current in Amperes	Cubic Inches per Hour	Pounds per Hour
200	5.4	$1\frac{1}{2}$
300	10.8	3
400	16.2	$4\frac{1}{2}$
500	21.6	6

In welding cast iron best results are secured by screwing studs into the piece each side of the crack and welding the studs to the filled metal.

Non-ferrous metals are not easily welded with the arc on account of the high temperature of the arc. Nearly all metals, however, can be welded electrically by the resistance method. The following table from the General Electric Company contains much information as to welding various metals.

Electric arc welding is affected by the condition of the electrodes. Dirty electrodes will not give a good weld. They can be detected by noting the kind and amount of sparks given off. Sparks from dirty electrodes will shoot off at all sorts of angles and vary greatly in intensity.

In welding mild steel to high-speed steel it is necessary to anneal properly to secure good results. It is advisable to transfer the hot steel immediately to an annealing furnace or to a carbon pack to insure slow cooling.

Principal Metals Encountered in Arc Welding

General Characteristics and Composition

Ferrous Metals.—The term steel is applied to a metal consisting principally of iron but containing carbon to the amount of from 0.2 to 2.0 per cent by weight. Where the carbon content is below this range we have the irons—wrought iron, Swedish and Norway iron, Ingot iron, etc. Where the carbon content is from $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent the metal is termed semi-steel and from $2\frac{1}{2}$ to 4 per cent carbon produces cast iron.

	Name	Amount of Distinguishing Alloying Material	Characteristics	Weldability
High carbon	Carbon—iron Cast iron	$2\frac{1}{2}$ to 4% carbon	Weak in tension. Brittle. No ductility.	Difficult
	Tool steel	0.90 to 1.65% carbon	Can be machined very hard. High tensile strength. Ductility low.	Practically impossible
Medium carbon	Spring steel	0.75 to 1.0% carbon	Can be hardened. High tensile strength. Ductility increased. Will stand bending	Unsatisfactory
	Casting steel	0.20 to 0.45% carbon	Will harden somewhat. Tensile strength less than above. Ductile and malleable.	Welding satisfactory
	Forging	Some castings up to 0.55.		
	Sheet steel Steel plate and structural steel	0.15 to 0.35% carbon	Will not harden much. Tensile strength. Ductile and malleable.	Welding satisfactory
Low carbon	Wrought iron Norway iron, etc. Ingot iron	0.03 to 0.08 carbon	Soft—ductile	Welding satisfactory

Alloy steels:			
Nickel steel	Approx. 3.5 % nickel 0.15 to 0.40 % carbon	Resistant to shock. Can be hardened. Shafts—gears.	Weldable Amount of carbon determines weldability.
Chromium steel	0.65 to 1.30 % chrom.	Very hard.	Below 0.35 % C O.K.
Chrome nickel	0.15 to 1.20 % carbon 0.15 to 0.55 % carbon	Gears—ball bearing races, etc.	Welding difficult
Steel	1.0 to 3.5 % nickel 0.45 to 1.75 % chrom.	Combination of two simple alloys.	
Manganese steel	1.0 to 1.3 % carbon 11 to 14 % manganese	Strong. Tough—cannot be machined. Hard—cannot be softened. Railway track work—crusher parts.	Weldable
	0.35 to 75 % carbon 0.60 to 1.15 manganese	Steel rails.	Weldable
Vanadium	Used in small amounts up to 0.25 % in combination with other alloys. Greatly increases resistance to fatigue.		
High speed steel	Up to 1 % carbon Up to 20 % tungsten Up to 4 % chromium Up to 1 % vanadium	Hard—strong.	Weldable

SPREADING LOCOMOTIVE FRAMES FOR WELDING

The same condition does not exist in every frame weld. Some 4 by 4-inch frames require more expansion than other frames of the same dimension, due to the location of the break or its relation to some section of the locomotive where more strength is required. When a frame is hard to expand because of its location or on account of being closely coupled at the point of fracture, it is very necessary that the expansion be increased a small amount to take care of the contraction that takes place more rapidly when the spreading device is taken out.

Frame welds are being made with manganese bronze on some roads to avoid the necessity of heating as much as where steel rods are used.

Table 1 gives the amount frames to be welded should be spread, the figures being based on experience.

TABLE 1.—AMOUNT OF SPREAD FRAMES SHOULD BE GIVEN FOR WELDING

Frame Section in Inches	Inch Spread to be Allowed
3 × 4	$\frac{1}{4}$
4 × 4	$\frac{5}{16}$
4 × 4½	$\frac{11}{32}$
4 × 5	$\frac{3}{8}$
5 × 6	$\frac{13}{32}$
6 × 8	$\frac{7}{16}$
6 × 9	$\frac{1}{2}$
8 × 8	$\frac{1}{2}$

From a paper presented at the October, 1923, meeting, Chicago Section American Welding Society.

WELDING LOCOMOTIVE FRAMES BY THERMIT

When fracture is between jaws they must be spread by using screw jack or other form of spreader. The gap should be opened from $\frac{3}{16}$ to $\frac{5}{16}$ inch, depending on the size of the frame and the amount of preheating. The longer the preheating the more the heat soaks back into the frame and the greater must be the allowance for contraction. The jack should not be removed too soon—about ½ hr. after weld is made is a good average.

Cast-iron thermit welds are hard to machine because the cast iron used contains over 3 per cent carbon and makes a high carbon steel in the weld. If finishing is necessary, it is usually done by grinding. Welds in wrought iron and steel machine more readily

GEARING

GEAR TEETH—SHAPES OF

Cycloidal or Epicycloidal.—A curved tooth generated by the point of a circle rolling away from the gear wheel or rack.

Involute.—A curved tooth generated by unwinding a tape or string from a cylinder. The rack tooth has straight sides.

Involute Standard.—The standard gear tooth has a $14\frac{1}{2}$ degree pressure angle which means that the teeth of a standard rack have straight sides $14\frac{1}{2}$ degrees from the vertical.

Involute—Stubbed.—A tooth shorter than the standard and usually with a 20-degree pressure angle.

GEARS—TEETH AND PARTS

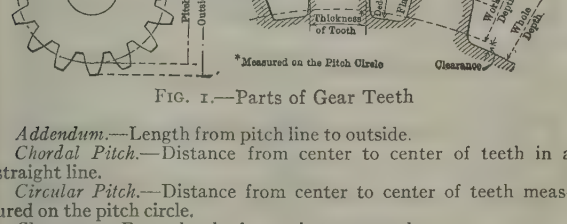


FIG. 1.—Parts of Gear Teeth

Addendum.—Length from pitch line to outside.

Chordal Pitch.—Distance from center to center of teeth in a straight line.

Circular Pitch.—Distance from center to center of teeth measured on the pitch circle.

Clearance.—Extra depth of space between teeth.

Coast Side of Tooth.—The back of tooth.

Drive Side of Tooth.—The side that drives.

Dedendum.—Length from pitch line to base of tooth.

Diametral Pitch.—Number of teeth divided by the pitch diameter or the teeth to each inch of pitch diameter.

Face.—Working surface of tooth outside of pitch line.

Flank.—Working surface of tooth below pitch line.

Outside Diameter.—Total diameter over teeth.

Pitch Diameter.—Diameter at the pitch line.

Pitch Line.—Line of contact of two cylinders which would have the same speed ratios as the gears.

Linear Pitch.—Sometimes used in rack measurement. Same as circular pitch of a gear.

Formulas for Gearing

Having	To Get	Rule	Formula
The Diametral Pitch	The Circular Pitch	Divide 3.1416 by the Diametral Pitch	$P' = \frac{3.1416}{P}$
The Pitch Diameter and the Number of Teeth	The Circular Pitch	Divide Pitch Diameter by the product of .3183 and Number of Teeth	$P' = \frac{D'}{.3183\,N}$
The Outside Diameter and the Number of Teeth	The Circular Pitch	Divide Outside Diameter by the product of .3183 and Number of Teeth plus 2	$P' = \frac{D}{.3183(N+2)}$
The Number of Teeth and the Circular Pitch	Pitch Diameter	The continued product of the Number of Teeth, the Circular Pitch and .3183	$D' = NP'.3183$
The Number of Teeth and the Outside Diameter	Pitch Diameter	Divide the product of Number of Teeth and Outside Diameter by Number of Teeth plus 2	$D' = \frac{ND}{N+2}$
The Outside Diameter and the Circular Pitch	Pitch Diameter	Subtract from the Outside Diameter the product of the Circular Pitch and .6366	$D' = D - (P'.6366)$
Addendum and the Number of Teeth	Pitch Diameter	Multiply the Number of Teeth by the Addendum	$D' = Ns$
The Number of Teeth and the Circular Pitch	Outside Diameter	The continued product of the Number of Teeth plus 2, the Circular Pitch and .3183	$D = \frac{(N+2)}{P'}.3183$
The Pitch Diameter and the Circular Pitch	Outside Diameter	Add to the Pitch Diameter the product of the Circular Pitch and .6366	$D = D' + (P'.6366)$
The Number of Teeth and the Addendum	Outside Diameter	Multiply Addendum by Number of Teeth plus 2	$D = s\,(N+2)$
The Pitch Diameter and the Circular Pitch	Number of Teeth	Divide the product of Pitch Diameter and 3.1416 by the Circular Pitch	$N = \frac{D'3.1416}{P'}$
The Circular Pitch	Thickness of Tooth	One half the Circular Pitch	$t = \frac{P'}{2}$
The Circular Pitch	Addendum	Multiply the Circular Pitch by .3183 or $s = \frac{D'}{N}$	$s = P'.3183$
The Circular Pitch	Root	Multiply the Circular Pitch by .3683	$s + f = P'.3683$
The Circular Pitch	Working Depth	Multiply the Circular Pitch by .6366	$D'' = P'.6366$
The Circular Pitch	Whole Depth	Multiply the Circular Pitch by .6866	$D'' = P'.6866$
The Circular Pitch	Clearance	Multiply the Circular Pitch by .05	$f = P'.05$
Thickness of Tooth	Clearance	One tenth the Thickness of Tooth at Pitch Line	$f = \frac{t}{10}$

FORMULAS FOR GEARING

Having	To Get	Rule	Formula
The Circular Pitch	The Diametral Pitch	Divide 3.1416 by the Circular Pitch	$P = \frac{3.1416}{P'}$
The Pitch Diameter and the Number of Teeth	The Diametral Pitch	Divide Number of Teeth by Pitch Diameter	$P = \frac{N}{D'}$
The Outside Diameter and the Number of Teeth	The Diametral Pitch	Divide Number of Teeth plus 2 by Outside Diameter	$P = \frac{N+2}{D}$
The Number of Teeth and the Diametral Pitch	Pitch Diameter	Divide Number of Teeth by the Diametral Pitch	$D' = \frac{N}{P}$
The Number of Teeth and the Outside Diameter	Pitch Diameter	Divide the Product of Outside Diameter and Number of Teeth by Number of Teeth plus 2	$D' = \frac{DN}{N+2}$
The Outside Diameter and the Diametral Pitch	Pitch Diameter	Subtract from the Outside Diameter the quotient of 2 divided by the Diametral Pitch	$D' = D - \frac{2}{P}$
Addendum and the Number of Teeth	Pitch Diameter	Multiply Addendum by the Number of Teeth	$D' = sN$
The Number of Teeth and the Diametral Pitch	Outside Diameter	Divide Number of Teeth plus 2 by the Diametral Pitch	$D = \frac{N+2}{P}$
The Pitch Diameter and the Diametral Pitch	Outside Diameter	Add to the Pitch Diameter the quotient of 2 divided by the Diametral Pitch	$D = D' + \frac{2}{P}$
The Pitch Diameter and the Number of Teeth	Outside Diameter	Divide the Number of Teeth plus 2, by the quotient of number of Teeth divided by Pitch Diameter	$D = \frac{N+2}{\frac{N}{D'}}$
The Number of Teeth and Addendum	Outside Diameter	Multiply the Number of Teeth plus 2 by Addendum	$D = (N+2)\,s$
The Pitch Diameter and the Diametral Pitch	Number of Teeth	Multiply Pitch Diameter by the Diametral Pitch	$N = D'P$
The Outside Diameter and the Diametral Pitch	Number of Teeth	Multiply Outside Diameter by the Diametral Pitch and subtract 2	$N = DP - 2$
The Diametral Pitch	Thickness of Tooth	Divide 1.5708 by the Diametral Pitch	$t = \frac{1.5708}{P}$
The Diametral Pitch	Addendum	Divide 1 by the Diametral Pitch or $s = \frac{D'}{N}$	$s = \frac{1}{P}$
The Diametral Pitch	Root	Divide 1.157 by the Diametral Pitch	$s + f = \frac{1.157}{P}$
The Diametral Pitch	Working Depth	Divide 2 by the Diametral Pitch	$D'' = \frac{2}{P}$
The Diametral Pitch	Whole Depth	Divide 2.157 by the Diametral Pitch	$D'' + f = \frac{2.157}{P}$
The Diametral Pitch	Clearance	Divide .157 by the Diametral Pitch	$f = \frac{.157}{P}$
Thickness of Tooth	Clearance	Divide Thickness of Tooth at pitch line by 10	$f = \frac{t}{10}$

Table of Corresponding Diametral and Circular Pitches

Table No. 1	
Diametral Pitch	Circular Pitch
1 1/2	2.5133
1 1/2	2.0944
1 3/4	1.7952
2	1.571
2 1/4	1.396
2 1/2	1.257
2 3/4	1.142
3	1.047
3 1/2	.898
4	.785
5	.628
6	.524
7	.449
8	.393
9	.349
10	.314
11	.286
12	.262
14	.224
16	.196
18	.175
20	.157
22	.143
24	.131
26	.121
28	.112
30	.105
32	.098
36	.087
40	.079
48	.065

Table No. 2	
Circular Pitch	Diametral Pitch
2	1.571
1 7/8	1.676
1 3/4	1.795
1 5/8	1.933
1 1/2	2.094
1 7/16	2.185
1 3/8	2.285
1 5/16	2.394
1 1/4	2.513
1 3/16	2.646
1 1/8	2.793
1 1/16	2.957
1	3.142
15/16	3.351
7/8	3.590
13/16	3.867
3/4	4.189
11/16	4.570
5/8	5.027
9/16	5.585
1/2	6.283
7/16	7.181
3/8	8.378
5/16	10.053
1/4	12.566
3/16	16.755
1/8	25.133
1/16	50.266

No. 1 table shows the diametral pitches with the corresponding circular pitches.

No. 2 table shows the circular pitches with the corresponding diametral pitches.

It is most natural to think of gears in circular or linear pitch and we soon get to know the size of any pitch, as 12, as being a little over $\frac{1}{4}$ inch from center to center. But the diametral system has many advantages in figuring gear blanks, center distances, etc.

The Center Distance of any pair of spur gears is found by adding one-half the pitch diameter of both gears.

CONSTANTS FOR DETERMINING CHORDAL PITCH AND RADIUS OF SPUR GEARS

P = Chordal Pitch of Teeth.
R = Radius of Pitch Circle.
N = Number of Teeth.
C = Constant. (See table below.)

$$\text{Chordal pitch} = \frac{\text{Radius of pitch circle}}{\text{Constant for number of teeth}}.$$

$$\text{Radius of pitch circle} = \text{Constant} \times \text{chordal pitch}.$$

$$\text{Constant for any number of teeth} = \frac{\text{Radius of pitch circle}}{\text{Chordal pitch of teeth}}.$$

EXAMPLES: 1. What is radius of pitch circle of a gear having 45 teeth, $1\frac{3}{4}$ inch pitch? Follow 40 in table to column 5 (making 45 teeth), and find 7.168. Multiply by pitch, $1\frac{3}{4}$ inch, and get 12.54 inches radius or 25.08 pitch diameter.

2. What is the chordal pitch of a gear 32 inches pitch diameter, 67 teeth? Follow 60 in table to column 7 and find 10.668. Divide radius ($\frac{1}{2}$ of 32 = 16 inches) by constant. $16 \div 10.668 = 1.5$ inch pitch.

3. What number of teeth has a gear of 1.5 inch chordal pitch and pitch diameter 32 inches? Divide by 2 to get radius. Divide this by chordal pitch which will give constant. $16 \div 1.5 = 10.666$. Look in table for this constant which will be found to represent 67 teeth.

TABLE OF CONSTANTS

N	0	1	2	3	4	5	6	7	8	9
0	0.000	0.000	0.500	0.577	0.707	0.851	1.000	1.152	1.307	1.462
10	1.618	1.774	1.932	2.089	2.247	2.405	2.563	2.721	2.879	3.038
20	3.196	3.355	3.513	3.672	3.831	3.989	4.148	4.307	4.465	4.624
30	4.783	4.942	5.101	5.260	5.419	5.578	.737	5.896	6.055	6.214
40	6.373	6.532	6.691	6.850	7.009	7.168	7.327	7.486	7.645	7.804
50	7.963	8.122	8.281	8.440	8.599	8.758	8.918	9.077	9.236	9.395
60	9.554	9.713	9.872	10.031	10.190	10.349	10.508	10.668	10.827	10.986
70	11.145	11.304	11.463	11.622	11.781	11.940	12.099	12.258	12.418	12.577
80	12.736	12.895	13.054	13.213	13.372	13.531	1 .690	13.849	14.008	14.168
90	14.327	14.486	14.645	14.804	14.963	15.123	15.282	15.441	15.600	15.759
100	15.918	16.077	16.236	16.395	16.554	16.713	16.873	17.032	17.191	17.350
110	17.509	17.668	17.828	17.987	18.146	18.305	18.464	18.624	18.783	18.942
120	19.101	19.260	19.419	19.579	19.738	19.897	20.056	20.215	20.375	20.534
130	20.693	20.852	21.011	21.170	21.330	21.489	21.648	21.807	21.966	22.126
140	22.285	22.444	22.603	22.762	22.921	23.081	23.240	23.399	23.558	23.717
150	23.877	24.036	24.195	24.354	24.513	24.672	24.832	24.991	25.150	25.309
160	25.468	25.627	25.787	25.946	26.105	26.264	26.423	26.583	26.742	26.901
170	27.060	27.219	27.378	27.538	27.697	27.856	28.015	28.174	28.334	28.493
180	28.652	28.811	28.970	29.129	29.289	29.448	29.607	29.766	29.925	30.085
190	30.242	30.403	30.562	30.721	30.880	31.040	31.199	31.358	31.517	31.676
200	31.830	31.989	32.148	32.307	32.446	32.625	32.785	32.944	33.103	33.262
210	33.427	33.586	33.746	33.905	34.064	34.223	34.382	34.542	34.701	34.860
220	35.019	35.178	35.337	35.497	35.656	35.815	35.974	36.133	36.293	36.452
230	36.611	36.770	36.929	37.088	37.248	37.407	37.566	37.725	37.884	38.044
240	38.203	38.362	38.521	38.680	38.839	38.999	39.158	39.317	39.476	39.635
250	39.795									

Gear Wheels

TABLE OF TOOTH PARTS —DIAMETRAL PITCH IN FIRST COLUMN

Diametral Pitch	Circular Pitch	Thickness of Tooth on Pitch Line	Addendum and $\frac{1''}{P}$	Working Depth of Tooth	Depth of Space below Pitch Line	Whole Depth of Tooth
P	P'	t	s	D''	$s+f$	$D''+f$
½	6.2832	3.1416	2.0000	4.0000	2.3142	4.3142
¾	4.1888	2.0944	1.3333	2.6666	1.5428	2.8761
1	3.1416	1.5708	1.0000	2.0000	1.1571	2.1571
1¼	2.5133	1.2566	.8000	1.6000	.9257	1.7257
1½	2.0944	1.0472	.6666	1.3333	.7714	1.4381
1¾	1.7952	.8976	.5714	1.1429	.6612	1.2326
2	1.5708	.7854	.5000	1.0000	.5785	1.0785
2¼	1.3963	.6981	.4444	.8888	.5143	.9587
2½	1.2566	.6283	.4000	.8000	.4628	.8628
2¾	1.1424	.5712	.3636	.7273	.4208	.7844
3	1.0472	.5236	.3333	.6666	.3857	.7190
3½	.8976	.4488	.2857	.5714	.3306	.6163
4	.7854	.3927	.2500	.5000	.2893	.5393
5	.6283	.3142	.2000	.4000	.2314	.4314
6	.5236	.2618	.1666	.3333	.1928	.3595
7	.4488	.2244	.1429	.2857	.1653	.3081
8	.3927	.1963	.1250	.2500	.1446	.2696
9	.3491	.1745	.1111	.2222	.1286	.2397
10	.3142	.1571	.1000	.2000	.1157	.2157
11	.2856	.1428	.0909	.1818	.1052	.1961
12	.2618	.1309	.0833	.1666	.0964	.1798
13	.2417	.1208	.0769	.1538	.0890	.1659
14	.2244	.1122	.0714	.1429	.0826	.1541

To obtain the size of any part of a diametral pitch not given in the table, divide the corresponding part of 1 diametral pitch by the pitch required.

As it is natural to think of gear pitches as the distance between teeth the same as threads, it is well to fix in the mind the approximate center distances of the pitches most in use. Or it is easy to remember that if the diametral pitch be divided by 3½ we have the teeth per inch on the pitch line. By this method we easily see that in a 10 diametral pitch gear there are approximately 3 teeth per inch while in a 22 diametral pitch there will be just 7 teeth to the inch.

TABLE OF TOOTH PARTS—*Continued*

DIAMETRAL PITCH IN FIRST COLUMN

Diametral Pitch	Circular Pitch	Thickness of Tooth on Pitch Line	Addendum and $\frac{1}{P}$	Working Depth of Tooth	Depth of Space below Pitch Line	Whole Depth of Tooth
P	P'	t	s	D''	$s+f$	$D''+f$
15	.2094	.1047	.0666	.1333	.0771	.1438
16	.1963	.0982	.0625	.1250	.0723	.1348
17	.1848	.0924	.0588	.1176	.0681	.1269
18	.1745	.0873	.0555	.1111	.0643	.1198
19	.1653	.0827	.0526	.1053	.0609	.1135
20	.1571	.0785	.0500	.1000	.0579	.1079
22	.1428	.0714	.0455	.0909	.0526	.0980
24	.1309	.0654	.0417	.0833	.0482	.0898
26	.1208	.0604	.0385	.0769	.0445	.0829
28	.1122	.0561	.0357	.0714	.0413	.0770
30	.1047	.0524	.0333	.0666	.0386	.0719
32	.0982	.0491	.0312	.0625	.0362	.0674
34	.0924	.0462	.0294	.0588	.0340	.0634
36	.0873	.0436	.0278	.0555	.0321	.0599
38	.0827	.0413	.0263	.0526	.0304	.0568
40	.0785	.0393	.0250	.0500	.0289	.0539
42	.0748	.0374	.0238	.0476	.0275	.0514
44	.0714	.0357	.0227	.0455	.0263	.0490
46	.0683	.0341	.0217	.0435	.0252	.0469
48	.0654	.0327	.0208	.0417	.0241	.0449
50	.0628	.0314	.0200	.0400	.0231	.0431
56	.0561	.0280	.0178	.0357	.0207	.0385
60	.0524	.0262	.0166	.0333	.0193	.0360

To obtain the size of any part of a diametral pitch not given in the table, divide the corresponding part of 1 diametral pitch by the pitch required.

As it is natural to think of gear pitches as the distance between teeth the same as threads, it is well to fix in the mind the approximate center distances of the pitches most in use. Or it is easy to remember that if the diametral pitch be divided by $3\frac{1}{2}$ we have the teeth per inch on the pitch line. By this method we easily see that in a 10 diametral pitch gear there are approximately 3 teeth per inch while in a 22 diametral pitch there will be just 7 teeth to the inch.

Gear Wheels

TABLE OF TOOTH PARTS—CIRCULAR PITCH IN FIRST COLUMN

Circular Pitch	Threads or Teeth per Inch Linear	Diametral Pitch	Thickness of Tooth on Pitch Line	Addendum and Modulde	Working Depth of Tooth	Depth of Space below Pitch Line	Whole Depth of Tooth	Width of Thread-Tool at End	Width of Thread at Top
P'	$\frac{1''}{P'}$	P	t	s	D''	$s+f$	$D''+f$	$P'\times.31$	$P'\times.335$
2	$\frac{1}{2}$	1.5708	1.0000	.6366	1.2732	.7366	1.3732	.6200	.6700
$1\frac{7}{8}$	$\frac{15}{32}$	1.6755	.9375	.5968	1.1937	.6906	1.2874	.5813	.6281
$1\frac{3}{4}$	$\frac{7}{16}$	1.7952	.8750	.5570	1.1141	.6445	1.2016	.5425	.5863
$1\frac{5}{8}$	$\frac{13}{32}$	1.9333	.8125	.5173	1.0345	.5985	1.1158	.5038	.5444
$1\frac{1}{2}$	$\frac{3}{8}$	2.0944	.7500	.4775	.9549	.5525	1.0299	.4650	.5025
$1\frac{7}{16}$	$\frac{11}{32}$	2.1855	.7187	.4576	.9151	.5294	.9870	.4456	.4816
$1\frac{3}{8}$	$\frac{11}{32}$	2.2848	.6875	.4377	.8754	.5064	.9441	.4262	.4606
$1\frac{1}{3}$	$\frac{3}{4}$	2.3562	.6666	.4244	.8488	.4910	.9154	.4133	.4466
$1\frac{5}{16}$	$\frac{21}{64}$	2.3936	.6562	.4178	.8356	.4834	.9012	.4069	.4397
$1\frac{1}{4}$	$\frac{5}{16}$	2.5133	.6250	.3979	.7958	.4604	.8583	.3875	.4188
$1\frac{1}{16}$	$\frac{19}{64}$	2.6456	.5937	.3780	.7560	.4374	.8156	.3681	.3978
$1\frac{1}{8}$	$\frac{9}{32}$	2.7925	.5625	.3581	.7162	.4143	.7724	.3488	.3769
$1\frac{1}{16}$	$\frac{17}{64}$	2.9568	.5312	.3382	.6764	.3913	.7295	.3294	.3559
1	1	3.1416	.5000	.3183	.6366	.3683	.6866	.3100	.3350
$\frac{15}{16}$	$1\frac{1}{15}$	3.3510	.4687	.2984	.5968	.3453	.6437	.2906	.3141
$\frac{7}{8}$	$1\frac{1}{7}$	3.5904	.4375	.2785	.5570	.3223	.6007	.2713	.2931
$\frac{13}{16}$	$1\frac{1}{13}$	3.8666	.4062	.2586	.5173	.2993	.5579	.2519	.2722
$\frac{3}{4}$	$1\frac{1}{4}$	3.9270	.4000	.2546	.5092	.2946	.5492	.2480	.2680
$\frac{11}{16}$	$1\frac{1}{3}$	4.1888	.3750	.2387	.4775	.2762	.5150	.2325	.2513
$\frac{5}{8}$	$1\frac{1}{11}$	4.5696	.3437	.2189	.4377	.2532	.4720	.2131	.2303
$\frac{9}{16}$	$1\frac{1}{2}$	4.7124	.3333	.2122	.4244	.2455	.4577	.2066	.2233
$\frac{1}{2}$	$1\frac{1}{8}$	5.0265	.3125	.1989	.3979	.2301	.4291	.1938	.2094
$\frac{7}{16}$	$1\frac{1}{4}$	5.2360	.3000	.1910	.3820	.2210	.4120	.1860	.2010
$\frac{3}{8}$	$1\frac{1}{4}$	5.4978	.2857	.1819	.3638	.2105	.3923	.1771	.1914
$\frac{5}{16}$	$1\frac{1}{6}$	5.5851	.2812	.1790	.3581	.2071	.3862	.1744	.1884

To obtain the size of any part of a circular pitch not given in the table, multiply the corresponding part of 1″ pitch by the pitch required.

As an example take a gear having 21 diametral pitch to find the various tooth parts. Take 1 diametral pitch and divide 3.1416 by 21 to find the corresponding circular pitch, which is .14951. The tooth thickness is 1.5708 ÷ 21 = .0748; the addendum is 1. ÷ 21 = .04761; the working depth is 2. ÷ 21. = .09522; the depth below

Table of Tooth Parts

CIRCULAR PITCH IN FIRST COLUMN

Circular Pitch	Threads or Teeth per Inch Linear	Diametral Pitch	Thickness of Tooth on Pitch Line	Addendum and Module	Working Depth of Tooth	Depth of Space below Pitch Line	Whole Depth of Tooth	Width of Thread-Tool at End	Width of Thread at Top
P'	$\frac{1''}{P'}$	P	t	s	D''	$s+f$	$D''+f$	$P'\times.31$	$P'\times.335$
1	2	6.2832	.2500	.1592	.3183	.1842	.3433	.1550	.1675
$\frac{7}{8}$	$2\frac{1}{7}$	7.0685	.2222	.1415	.2830	.1637	.3052	.1378	.1489
$\frac{13}{16}$	$2\frac{2}{13}$	7.1808	.2187	.1393	.2785	.1611	.3003	.1356	.1466
$\frac{3}{4}$	$2\frac{1}{3}$	7.3304	.2143	.1364	.2728	.1578	.2942	.1328	.1436
$\frac{5}{8}$	$2\frac{1}{2}$	7.8540	.2000	.1273	.2546	.1473	.2746	.1240	.1340
$\frac{11}{16}$	$2\frac{2}{11}$	8.3776	.1875	.1194	.2387	.1381	.2575	.1163	.1256
$\frac{11}{11}$	$2\frac{3}{4}$	8.6394	.1818	.1158	.2316	.1340	.2498	.1127	.1218
$\frac{1}{3}$	3	9.4248	.1666	.1061	.2122	.1228	.2289	.1033	.1117
$\frac{15}{16}$	$3\frac{1}{5}$	10.0531	.1562	.0995	.1989	.1151	.2146	.0969	.1047
$\frac{16}{16}$	$3\frac{3}{16}$	10.4719	.1500	.0955	.1910	.1105	.2060	.0930	.1005
$\frac{7}{7}$	$3\frac{1}{2}$	10.9956	.1429	.0909	.1819	.1052	.1962	.0886	.0957
$\frac{1}{4}$	4	12.5664	.1250	.0796	.1591	.0921	.1716	.0775	.0838
$\frac{9}{9}$	$4\frac{1}{2}$	14.1372	.1111	.0707	.1415	.0818	.1526	.0689	.0744
$\frac{1}{5}$	5	15.7080	.1000	.0637	.1273	.0737	.1373	.0620	.0670
$\frac{11}{11}$	$5\frac{1}{2}$	16.7552	.0937	.0597	.1194	.0690	.1287	.0581	.0628
$\frac{1}{6}$	6	17.2788	.0909	.0579	.1158	.0670	.1249	.0564	.0609
$\frac{1}{6}$	6	18.8496	.0833	.0531	.1061	.0614	.1144	.0517	.0558
$\frac{13}{13}$	$6\frac{1}{2}$	20.4203	.0769	.0489	.0978	.0566	.1055	.0477	.0515
$\frac{1}{7}$	7	21.9911	.0714	.0455	.0910	.0526	.0981	.0443	.0479
$\frac{15}{15}$	$7\frac{1}{2}$	23.5619	.0666	.0425	.0850	.0492	.0917	.0414	.0446
$\frac{1}{8}$	8	25.1327	.0625	.0398	.0796	.0460	.0858	.0388	.0419
$\frac{1}{9}$	9	28.2743	.0555	.0354	.0707	.0409	.0763	.0344	.0372
$\frac{1}{10}$	10	31.4159	.0500	.0318	.0637	.0368	.0687	.0310	.0335
$\frac{1}{16}$	16	50.2655	.0312	.0199	.0398	.0230	.0429	.0194	.0209
$\frac{1}{20}$	20	62.8318	.0250	.0159	.0318	.0184	.0343	.0155	.0167

To obtain the size of any part of a circular pitch not given in the table, multiply the corresponding part of 1″ pitch by the pitch required.

pitch line is $1.1571 \div 21 = .0551$ and the whole depth is $2.1571 \div 21 = .1027$ inches. These could also have been obtained by splitting the difference between the figures for 20 and 22 pitch. The same can be done for circular pitch except that we multiply instead of divide.

LAYING OUT SPUR GEAR BLANKS

DECIDE upon the size wanted, remembering that 12-pitch teeth are $\frac{1}{12}$ deep and 8-pitch—as in the drawing—$\frac{1}{8}$ deep, etc. Should it be 8 pitch, as shown in the cut, draw a circle measuring as many eighths of an inch in diameter as there are to be teeth in the gear. This circle is called the Pitch Line. Then with a radius $\frac{1}{8}$ of an inch larger, draw another circle from the same center, which will give the outside diameter of the gear, or $\frac{2}{8}$ larger than the pitch circle. Thus we have for the diameter of an 8-pitch gear of 24 teeth, $\frac{26}{8}$. Should there be 16 teeth, as in the small spur gear in the cut, the outside diameter would be $\frac{18}{8}$, the number of teeth being always two less than there are eighths—*when it is* 8 *pitch*—in the outside diameter.

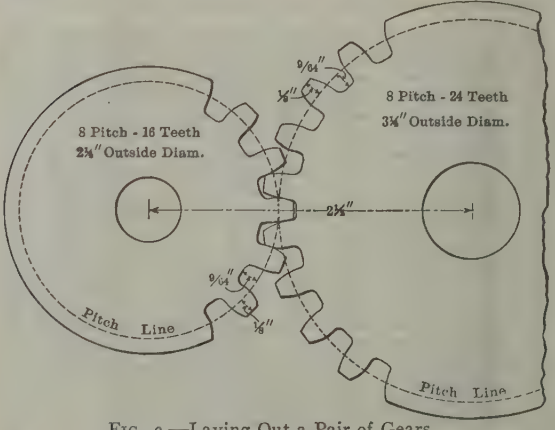


FIG. 2.—Laying Out a Pair of Gears

The distance from the pitch line to the bottom of the teeth is the same as to the top, excepting the clearance, which varies from $\frac{1}{8}$ of the pitch to $\frac{1}{10}$ of the thickness of the tooth at the pitch line. This latter is used by Brown & Sharpe and many others, but the clearance being provided for in the cutters the two gears would be laid out to mesh together just $\frac{2}{8}$.

These rules apply to all pitches, so that the outside diameter of a 5-pitch gear with 24 teeth would be $\frac{26}{5}$; if a 3-pitch gear with 40 teeth it would be $\frac{42}{3}$. Again, if a blank be $4\frac{1}{6}$ ($\frac{25}{6}$) in diameter, and cut 6 pitch, it should contain 23 teeth.

ACTUAL SIZE OF DIAMETRAL PITCHES

It is not always easy to judge or imagine just how large a given pitch is when measured by the diametral system. To make it easy to see just what any pitch looks like the actual sizes of twelve



20 P.

0.1571 C.P.
1.270 M.M.



18 P.

0.1745 C.P.
1.411 M.M.



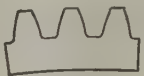
16 P.

0.1963 C.P.
1.587 M.M.



14 P.

0.2244 C.P.
1.814 M.M.



12 P.

0.2618 C.P.
2.116 M.M.



10 P.

0.3142 C.P.
2.540 M.M.



9 P.

0.3491 C.P.
2.822 M.M.



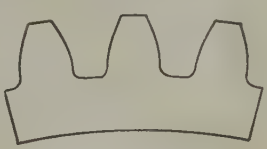
8 P.

0.3927 C.P.
3.175 M.M.



7 P.

0.4488 C.P.
3.628 M.M.



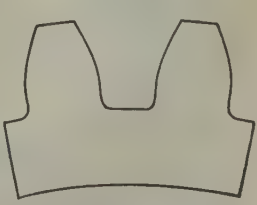
6 P

0.5236 C.P.
4.233 M.M.



5 P.

0.6283 C.P.
5.080 M.M.



4 P.

0.7854 C.P.
6.350 M.M.

C.P. = Circular Pitch. M.M. = m/m Module.

diametral pitches are given on the preceding page, ranging from 20 to 4 teeth per inch of diameter on the pitch line, so that a good idea of the size of any of these teeth can be had at a glance.

PRESSURE ANGLES

The pressure angles of gear teeth means the angle at which one tooth presses against the other and can best be shown by the pinion and rack, Figs. 3 and 4.

The standard tooth has a $14\frac{1}{2}$-degree pressure angle. As the sides of an involute rack tooth are straight, and at the pressure

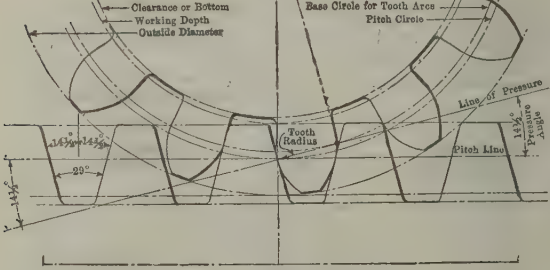


FIG. 3.—Standard Tooth

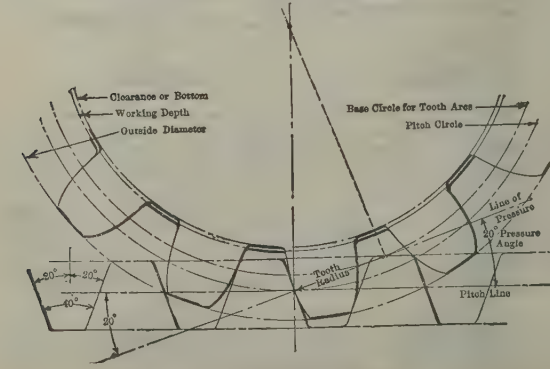


FIG. 4.—Stubbed Tooth

angle from the perpendicular, draw the line of pressure at $14\frac{1}{2}$ degrees from the pitch line.

The difference between the $14\frac{1}{2}$- and 20-degree pressure angles can be seen by comparing Figs. 3 and 4. Not only is the tooth shorter, but the base is broader.

STUB-TOOTH GEARS

Any tooth shorter than the regular standard length is called a "stub" tooth, but like the bastard thread there have been many kinds. In 1899 the Fellows Gear Shaper Company introduced a short tooth with a 20-degree pressure angle instead of the usual $14\frac{1}{2}$-degree. This gives a broader flank to the tooth and makes a stronger gear, especially for small pinions where strength is needed. While the Fellows tooth is shorter than the standard tooth there is no fixed relation between them, as, on account of the tooth depth graduations of the gear shaper, it was thought best to give the new tooth depth in the same scale which is shown in table on this page. This means that if the pitch is 4 it has the depth of a 5-pitch standard tooth divided as shown. The clearance is one-quarter the addendum or dedendum.

Gear Tooth Parts (20-Degree Pressure Angle, Stub-Tooth Form)

THE FELLOWS GEAR SHAPER CO. STANDARD

Diametral Pitch	Dimensions in Inches				
	Thickness on Pitch Line	Addendum	Dedendum Plus Clearance	Whole Depth of Tooth	Double Depth of Tooth
$\frac{3}{4}$	0.5236	0.2500	0.3125	0.5625	1.1250
$\frac{4}{5}$	0.3927	0.2000	0.2500	0.4500	0.9000
$\frac{5}{6}$	0.3142	0.1429	0.1786	0.3215	0.6430
$\frac{6}{7}$	0.2618	0.1250	0.1562	0.2812	0.5625
$\frac{7}{8}$	0.2244	0.1111	0.1389	0.2500	0.5000
$\frac{8}{9}$	0.1963	0.1000	0.1250	0.2250	0.4500
$\frac{9}{10}$	0.1745	0.0909	0.1136	0.2045	0.4090
$\frac{10}{11}$	0.1571	0.0833	0.1042	0.1875	0.3750
$\frac{11}{12}$	0.1309	0.0714	0.0893	0.1607	0.3214
$\frac{12}{13}$	0.1208	0.0625	0.0781	0.1406	0.2812
$\frac{13}{14}$	0.1122	0.0555	0.0694	0.1250	0.2500
$\frac{14}{15}$	0.1047	0.0500	0.0625	0.1125	0.2250
$\frac{15}{16}$	0.0982	0.0476	0.0595	0.1071	0.2142
$\frac{16}{17}$	0.0924	0.0454	0.0568	0.1023	0.2046
$\frac{17}{18}$	0.0873	0.0417	0.0521	0.0937	0.1875
$\frac{18}{19}$	0.0827	0.0400	0.0500	0.0900	0.1800
$\frac{19}{20}$	0.0785	0.0385	0.0481	0.0865	0.1731
$\frac{20}{21}$	0.0748	0.0357	0.0446	0.0803	0.1607
$\frac{21}{22}$	0.0714	0.0345	0.0431	0.0776	0.1552
$\frac{22}{23}$	0.0683	0.0330	0.0412	0.0742	0.1485
$\frac{23}{24}$	0.0654	0.0312	0.0391	0.0703	0.1406

Outside Diameters of Stub Tooth Gears

$$\text{Pitch Dia.} = \frac{\text{No. Teeth}}{\text{Numerator Pitch}} \quad \text{Add.} = \frac{1}{\text{Denom. Pitch}} \quad \text{Clear} = \frac{\text{Add}}{4}$$

$$\text{Out. Dia.} = \text{P.D.} + \left(2 \times \frac{1}{\text{Denom. Pitch}}\right) \quad \text{Ded.} = \frac{1}{\text{Denom. Pitch}}$$

Pitch	$\frac{1}{4}$	$\frac{4}{8}$	$\frac{5}{7}$	$\frac{6}{8}$	$\frac{7}{8}$	$\frac{8}{10}$	$\frac{9}{11}$	$\frac{10}{12}$	$\frac{12}{14}$	$\frac{16}{21}$
Number of Teeth										
14	5.167	3.900	3.086	2.583	2.222	1.950	1.738	1.567	1.310	.970
15	5.500	4.150	3.286	2.750	2.365	2.075	1.849	1.667	1.393	1.033
16	5.833	4.400	3.486	2.917	2.508	2.200	1.960	1.767	1.476	1.095
17	6.167	4.650	3.686	3.083	2.651	2.325	2.071	1.867	1.560	1.158
18	6.500	4.900	3.886	3.250	2.794	2.450	2.182	1.967	1.643	1.220
19	6.833	5.150	4.086	3.417	2.937	2.575	2.292	2.067	1.726	1.283
20	7.167	5.400	4.286	3.583	3.080	2.700	2.404	2.167	1.809	1.345
22	7.833	5.900	4.686	3.917	3.365	2.950	2.626	2.367	1.976	1.470
24	8.500	6.400	5.086	4.250	3.651	3.200	2.849	2.567	2.143	1.595
26	9.167	6.900	5.486	4.583	3.937	3.450	3.071	2.767	2.310	1.720
28	9.833	7.400	5.886	4.917	4.223	3.700	3.293	2.967	2.476	1.845
30	10.500	7.900	6.286	5.250	4.508	3.950	3.515	3.167	2.643	1.970
32	11.167	8.400	6.686	5.583	4.794	4.200	3.738	3.367	2.809	2.095
34	11.833	8.900	7.086	5.917	5.080	4.450	3.960	3.567	2.976	2.220
36	12.500	9.400	7.486	6.250	5.365	4.700	4.182	3.767	3.143	2.345
38	13.167	9.900	7.886	6.583	5.651	4.950	4.404	3.967	3.310	2.470
40	13.833	10.400	8.286	6.917	5.937	5.200	4.626	4.167	3.476	2.595
42	14.500	10.900	8.686	7.250	6.222	5.450	4.849	4.367	3.643	2.720
44	15.167	11.400	9.086	7.583	6.508	5.700	5.071	4.567	3.809	2.845
46	15.833	11.900	9.486	7.917	6.794	5.950	5.293	4.767	3.976	2.970
48	16.500	12.400	9.886	8.250	7.080	6.200	5.515	4.967	4.143	3.095
50	17.167	12.900	10.286	8.583	7.365	6.450	5.738	5.167	4.310	3.220
52	17.833	13.400	10.686	8.917	7.651	6.700	5.960	5.367	4.476	3.345
54	18.500	13.900	11.086	9.250	7.937	6.950	6.182	5.567	4.643	3.470
56	19.167	14.400	11.486	9.583	8.222	7.200	6.404	5.767	4.809	3.595
58	19.833	14.900	11.886	9.917	8.508	7.450	6.626	5.967	4.976	3.720
60	20.500	15.400	12.286	10.250	8.794	7.700	6.849	6.167	5.143	3.845
62	21.167	15.900	12.686	10.583	9.080	7.950	7.071	6.367	5.310	3.970
64	21.833	16.400	13.086	10.917	9.365	8.200	7.293	6.567	5.476	4.095
66	22.500	16.900	13.486	11.250	9.651	8.450	7.515	6.767	6.643	4.220
68	23.167	17.400	13.886	11.583	9.937	8.700	7.738	6.967	6.809	4.345
70	23.833	17.900	14.286	11.917	10.222	8.950	7.960	7.167	6.976	4.470

Table for Turning and Cutting Gear Blanks for Standard Length Tooth

Pitch	16	12	10	8	Pitch	16	12	10	8
Depth of Tooth	.135	.180	.216	.270	Depth of Tooth	.135	.180	.216	.270
No. of Teeth	Outside Diameter				No. of Teeth	Outside Diameter			
10	3/4	1	1 1/10	1 1/2	51	3 15/16	4 1/2	5 9/10	6 3/8
11	13/16	1 1/2	1 8/10	1 5/8	52	3 7/8	4 6/10	5 4/10	6 3/4
12	7/8	1 2/3	1 4/10	1 3/4	53	3 15/16	4 1/2	5 5/10	6 7/8
13	1 5/16	1 3/4	1 6/10	1 7/8	54	3 1/2	4 1/2	5 6/10	7
14	1	1 4/5	1 6/10	2	55	3 9/16	4 1/2	5 7/10	7 1/8
15	1 1/16	1 1/2	1 7/10	2 1/8	56	3 5/8	4 1/2	5 8/10	7 1/4
16	1 1/8	1 6/10	1 8/10	2 1/4	57	3 11/16	4 1/2	5 9/10	7 3/8
17	1 3/16	1 7/10	1 9/10	2 3/8	58	3 3/4	5	6	7 1/2
18	1 1/4	1 8/10	2	2 1/2	59	3 13/16	5 1/2	6 1/10	7 5/8
19	1 5/16	1 9/10	2 1/10	2 5/8	60	3 7/8	5 2/3	6 2/10	7 3/4
20	1 3/8	1 10/12	2 2/10	2 3/4	61	3 15/16	5 1/2	6 3/10	7 7/8
21	1 7/16	1 11/12	2 3/10	2 7/8	62	4	5 1/2	6 4/10	8
22	1 1/2	2	2 4/10	3	63	4 1/16	5 1/2	6 5/10	8 1/8
23	1 9/16	2 1/12	2 5/10	3 1/8	64	4 1/8	5 1/2	6 6/10	8 1/4
24	1 5/8	2 2/12	2 6/10	3 1/4	65	4 1/16	5 1/2	6 7/10	8 3/8
25	1 11/16	2 3/12	2 7/10	3 3/8	66	4 1/4	5 1/2	6 8/10	8 1/2
26	1 3/4	2 4/12	2 8/10	3 1/2	67	4 5/16	5 1/2	6 9/10	8 5/8
27	1 13/16	2 5/12	2 9/10	3 5/8	68	4 3/8	5 10/12	7	8 3/4
28	1 7/8	2 6/12	3	3 3/4	69	4 7/16	5 11/12	7 1/10	8 7/8
29	1 15/16	2 7/12	3 1/10	3 7/8	70	4 1/2	6	7 2/10	9
30	2	2 8/12	3 2/10	4	71	4 9/16	6 1/2	7 3/10	9 1/8
31	2 1/16	2 9/12	3 3/10	4 1/8	72	4 5/8	6 1/2	7 4/10	9 1/4
32	2 1/8	2 10/12	3 4/10	4 1/4	73	4 11/16	6 3/10	7 5/10	9 3/8
33	2 3/16	2 11/12	3 5/10	4 3/8	74	4 3/4	6 4/10	7 6/10	9 1/2
34	2 1/4	3	3 6/10	4 1/2	75	4 13/16	6 1/2	7 7/10	9 5/8
35	2 5/16	3 1/12	3 7/10	4 5/8	76	4 7/8	6 6/10	7 8/10	9 3/4
36	2 3/8	3 2/12	3 8/10	4 3/4	77	4 15/16	6 7/10	7 9/10	9 7/8
37	2 7/16	3 3/12	3 9/10	4 7/8	78	5	6 8/10	8	10
38	2 1/2	3 4/12	4	5	79	5 1/16	6 9/10	8 1/10	10 1/8
39	2 9/16	3 5/12	4 1/10	5 1/8	80	5 1/8	6 10/12	8 2/10	10 1/4
40	2 5/8	3 6/12	4 2/10	5 1/4	81	5 1/16	6 11/12	8 3/10	10 3/8
41	2 11/16	3 7/12	4 3/10	5 3/8	82	5 1/4	7	8 4/10	10 1/2
42	2 3/4	3 8/12	4 4/10	5 1/2	83	5 5/16	7 1/2	8 5/10	10 5/8
43	2 13/16	3 9/12	4 5/10	5 5/8	84	5 3/8	7 1/2	8 6/10	10 3/4
44	2 7/8	3 10/12	4 6/10	5 3/4	85	5 7/16	7 1/2	8 7/10	10 7/8
45	2 15/16	3 11/12	4 7/10	5 7/8	86	5 1/2	7 1/2	8 8/10	11
46	3	4	4 8/10	6	87	5 9/16	7 5/12	8 9/10	11 1/8
47	3 1/16	4 1/12	4 9/10	6 1/8	88	5 5/8	7 6/12	9	11 1/4
48	3 1/8	4 2/12	5	6 1/4	89	5 11/16	7 7/12	9 1/10	11 3/8
49	3 3/16	4 3/12	5 1/10	6 3/8	90	5 3/4	7 8/12	9 2/10	11 1/2
50	3 1/4	4 4/12	5 2/10	6 1/2	91	5 13/16	7 9/12	9 3/10	11 5/8

Pitch Diameters of Standard Gears

The accompanying tables require little explanation, being simply given to save time in laying out gear trains. Having the diametral pitch and the number of teeth, the pitch diameter is easily found from the tables. They also show the corresponding circular pitch, designated by C. P.

Having the pitch diameter, the outside diameter can easily be found by adding two parts of the pitch of standard gears. The outside diameter of any gear with standard teeth is the same as the pitch diameter of two more teeth.

PITCH DIAMETER OF GEARS WHEN DIAMETRAL PITCH AND THE NUMBER OF TEETH ARE KNOWN

D.P. C.P.	1.5 2.094	2 1.571	2.5 1.257	3 1.047	4 0.785	5 0.628	6 0.524	8 0.393	10 0.3142	12 0.2618	14 0.2244	16 0.1963	20 0.1571
No. T													
15	10.000	7.50	6.00	5.000	3.75	3.00	2.500	1.875	1.5	1.250	1.071	0.937	0.75
16	10.666	8.00	6.40	5.333	4.00	3.20	2.666	2.000	1.6	1.333	1.142	1.000	0.80
17	11.333	8.50	6.80	5.666	4.25	3.40	2.833	2.125	1.7	1.416	1.214	1.062	0.85
18	12.000	9.00	7.20	6.000	4.50	3.60	3.000	2.250	1.8	1.500	1.285	1.125	0.90
19	12.666	9.50	7.60	6.333	4.75	3.80	3.166	2.375	1.9	1.583	1.357	1.187	0.95
20	13.333	10.00	8.00	6.666	5.00	4.00	3.333	2.500	2.0	1.666	1.428	1.250	1.00
21	14.000	10.50	8.40	7.000	5.25	4.20	3.500	2.625	2.1	1.750	1.500	1.312	1.05
22	14.666	11.00	8.80	7.333	5.50	4.40	3.666	2.750	2.2	1.833	1.571	1.375	1.10
23	15.333	11.50	9.20	7.666	5.75	4.60	3.833	2.875	2.3	1.916	1.642	1.437	1.15
24	16.000	12.00	9.60	8.000	6.00	4.80	4.000	3.000	2.4	2.000	1.714	1.500	1.20
25	16.666	12.50	10.00	8.333	6.25	5.00	4.166	3.125	2.5	2.083	1.785	1.562	1.25
26	17.333	13.00	10.40	8.666	6.50	5.20	4.333	3.250	2.6	2.167	1.857	1.625	1.30
27	18.000	13.50	10.80	9.000	6.75	5.40	4.500	3.375	2.7	2.250	1.928	1.687	1.35
28	18.666	14.00	11.20	9.333	7.00	5.60	4.666	3.500	2.8	2.333	2.000	1.750	1.40
29	19.333	14.50	11.60	9.666	7.25	5.80	4.833	3.625	2.9	2.416	2.071	1.812	1.45
30	20.000	15.00	12.00	10.000	7.50	6.00	5.000	3.750	3.0	2.500	2.142	1.875	1.50
31	20.666	15.50	12.40	10.333	7.75	6.20	5.166	3.875	3.1	2.583	2.214	1.937	1.55
32	21.333	16.00	12.80	10.666	8.00	6.40	5.333	4.000	3.2	2.666	2.285	2.000	1.60
33	22.000	16.50	13.20	11.000	8.25	6.60	5.500	4.125	3.3	2.750	2.357	2.062	1.65
34	22.666	17.00	13.60	11.333	8.50	6.80	5.666	4.250	3.4	2.833	2.428	2.125	1.70
35	23.333	17.50	14.00	11.666	8.75	7.00	5.833	4.375	3.5	2.916	2.500	2.187	1.75

D.P. C.P.	1.5 2.094	2 1.571	2.5 1.257	3 1.047	4 0.785	5 0.628	6 0.524	8 0.393	10 0.3142	12 0.2618	14 0.2244	16 0.1963	20 0.1571
No. T													
36.....	24.000	18.00	14.40	12.000	9.00	7.20	6.000	4.500	3.6	3.000	2.571	2.250	1.80
37.....	24.666	18.50	14.80	12.333	9.25	7.40	6.166	4.625	3.7	3.083	2.642	2.312	1.85
38.....	25.333	19.00	15.20	12.666	9.50	7.60	6.333	4.750	3.8	3.167	2.714	2.375	1.90
39.....	26.000	19.50	15.60	13.000	9.75	7.80	6.500	4.875	3.9	3.250	2.785	2.437	1.95
40.....	26.666	20.00	16.00	13.333	10.00	8.00	6.666	5.000	4.0	3.333	2.857	2.500	2.00
41.....	27.333	20.50	16.40	13.666	10.25	8.20	6.833	5.125	4.1	3.416	2.928	2.562	2.05
42.....	28.000	21.00	16.80	14.000	10.50	8.40	7.000	5.250	4.2	3.500	3.000	2.625	2.10
43.....	28.666	21.50	17.20	14.333	10.75	8.60	7.166	5.375	4.3	3.583	3.071	2.687	2.15
44.....	29.333	22.00	17.60	14.666	11.00	8.80	7.333	5.500	4.4	3.666	3.142	2.750	2.20
45.....	30.000	22.50	18.00	15.000	11.25	9.00	7.500	5.625	4.5	3.750	3.214	2.812	2.25
46.....	30.666	23.00	18.40	15.333	11.50	9.20	7.666	5.750	4.6	3.833	3.285	2.875	2.30
47.....	31.333	23.50	18.80	15.666	11.75	9.40	7.833	5.875	4.7	3.916	3.357	2.937	2.35
48.....	32.000	24.00	19.20	16.000	12.00	9.60	8.000	6.000	4.8	4.000	3.428	3.000	2.40
49.....	32.666	24.50	19.60	16.333	12.25	9.80	8.166	6.125	4.9	4.083	3.500	3.062	2.45
50.....	33.333	25.00	20.00	16.666	12.50	10.00	8.333	6.250	5.0	4.167	3.571	3.125	2.50
51.....	34.000	25.50	20.40	17.000	12.75	10.20	8.500	6.375	5.1	4.250	3.642	3.187	2.55
52.....	34.666	26.00	20.80	17.333	13.00	10.40	8.666	6.500	5.2	4.333	3.714	3.250	2.60
53.....	35.333	26.50	21.20	17.666	13.25	10.60	8.833	6.625	5.3	4.416	3.785	3.312	2.65
54.....	36.000	27.00	21.60	18.000	13.50	10.80	9.000	6.750	5.4	4.500	3.857	3.375	2.70
55.....	36.666	27.50	22.00	18.333	13.75	11.00	9.166	6.875	5.5	4.583	3.928	3.437	2.75
56.....	37.333	28.00	22.40	18.666	14.00	11.20	9.333	7.000	5.6	4.666	4.000	3.500	2.80
57.....	38.000	28.50	22.80	19.000	14.25	11.40	9.500	7.125	5.7	4.750	4.071	3.562	2.85
58.....	38.666	29.00	23.20	19.333	14.50	11.60	9.666	7.250	5.8	4.833	4.142	3.625	2.90
59.....	39.333	29.50	23.60	19.666	14.75	11.80	9.833	7.375	5.9	4.916	4.214	3 687	2.95
60.....	40.000	30.00	24.00	20.000	15.00	12.00	10.000	7.500	6.0	5.000	4.285	3.750	3.00
61.....	40.666	30.50	24.40	20.333	15.25	12.20	10.166	7.625	6.1	5.083	4.357	3.812	3.05
62.....	41.333	31.00	24.80	20.666	15.50	12.40	10.333	7.750	6.2	5.167	4.428	3.875	3.10
63.....	42.000	31.50	25.20	21.000	15.75	12.60	10.500	7.875	6.3	5.250	4.500	3.937	3.15
64.....	42.666	32.00	25.60	21.333	16.00	12.80	10.666	8.000	6.4	5.333	4.571	4.000	3.20
65.....	43.333	32.50	26.00	21.666	16.25	13.00	10.833	8.125	6.5	5.416	4.642	4.062	3.25
66.....	44.000	33.00	26.40	22.000	16.50	13.20	11.000	8.250	6.6	5.500	4.714	4.125	3.30

PITCH DIAMETER OF GEARS WHEN DIAMETRAL PITCH AND THE NUMBER OF TEETH ARE KNOWN. (*Continued*)

D.P. C.P.	1.5 2.094	2 1.571	2.5 1.257	3 1.047	4 0.785	5 0.628	6 0.524	8 0.393	10 0.3142	12 0.2618	14 0.2244	16 0.1963	20 0.1571
No. T													
67.....	44.666	33.50	26.80	22.333	16.75	13.40	11.166	8.375	6.7	5.583	4.785	4.187	3.35
68.....	45.333	34.00	27.20	22.666	17.00	13.60	11.333	8.500	6.8	5.666	4.857	4.250	3.40
69.....	46.000	34.50	27.60	23.000	17.25	13.80	11.500	8.625	6.9	5.750	4.928	4.312	3.45
70.....	46.666	35.00	28.00	23.333	17.50	14.00	11.666	8.750	7.0	5.833	5.000	4.375	3.50
71.....	47.333	35.50	28.40	23.666	17.75	14.20	11.833	8.875	7.1	5.916	5.071	4.437	3.55
72.....	48.000	36.00	28.80	24.000	18.00	14.40	12.000	9.000	7.2	6.000	5.142	4.500	3.60
73.....	48.666	36.50	29.20	24.333	18.25	14.60	12.166	9.125	7.3	6.083	5.214	4.562	3.65
74.....	49.333	37.00	29.60	24.666	18.50	14.80	12.333	9.250	7.4	6.167	5.285	4.625	3.70
75.....	50.000	37.50	30.00	25.000	18.75	15.00	12.500	9.375	7.5	6.250	5.357	4.687	3.75
76.....	50.666	38.00	30.40	25.333	19.00	15.20	12.666	9.500	7.6	6.333	5.428	4.750	3.80
77.....	51.333	38.50	30.80	25.666	19.25	15.40	12.833	9.625	7.7	6.416	5.500	4.812	3.85
78.....	52.000	39.00	31.20	26.000	19.50	15.60	13.000	9.750	7.8	6.500	5.571	4.875	3.90
79.....	52.666	39.50	31.60	26.333	19.75	15.80	13.166	9.875	7.9	6.583	5.642	4.937	3.95
80.....	53.333	40.00	32.00	26.666	20.00	16.00	13.333	10.000	8.0	6.666	5.714	5.000	4.00
81.....	54.000	40.50	32.40	27.000	20.25	16.20	13.500	10.125	8.1	6.750	5.785	5.062	4.05
82.....	54.666	41.00	32.80	27.333	20.50	16.40	13.666	10.250	8.2	6.833	5.857	5.125	4.10
83.....	55.333	41.50	33.20	27.666	20.75	16.60	13.833	10.375	8.3	6.916	5.928	5.187	4.15
84.....	56.000	42.00	33.60	28.000	21.00	16.80	14.000	10.500	8.4	7.000	6.000	5.250	4.20
85.....	56.666	42.50	34.00	28.333	21.25	17.00	14.166	10.625	8.5	7.083	6.071	5.312	4.25
86.....	57.333	43.00	34.40	28.666	21.50	17.20	14.333	10.750	8.6	7.167	6.142	5.375	4.30
87.....	58.000	43.50	34.80	29.000	21.75	17.40	14.500	10.875	8.7	7.250	6.214	5.437	4.35
88.....	58.666	44.00	35.20	29.333	22.00	17.60	14.666	11.000	8.8	7.333	6.285	5.500	4.40
89.....	59.333	44.50	35.60	29.666	22.25	17.80	14.833	11.125	8.9	7.416	6.357	5.562	4.45
90.....	60.000	45.00	36.00	30.000	22.50	18.00	15.000	11.250	9.0	7.500	6.428	5.625	4.50
91.....	60.666	45.50	36.40	30.333	22.75	18.20	15.166	11.375	9.1	7.583	6.500	5.687	4.55
92.....	61.333	46.00	36.80	30.666	23.00	18.40	15.333	11.500	9.2	7.666	6.571	5.750	4.60
93.....	62.000	46.50	37.20	31.000	23.25	18.60	15.500	11.625	9.3	7.750	6.642	5.812	4.65
94.....	62.666	47.00	37.60	31.333	23.50	18.80	15.666	11.750	9.4	7.833	6.714	5.875	4.70
95.....	63.333	47.50	38.00	31.666	23.75	19.00	15.833	11.875	9.5	7.916	6.785	5.937	4.75
96.....	64.000	48.00	38.40	32.000	24.00	19.20	16.000	12.000	9.6	8.000	6.857	6.000	4.80
97.....	64.666	48.50	38.80	32.333	24.25	19.40	16.166	12.125	9.7	8.083	6.928	6.062	4.85
98.....	65.333	49.00	39.20	32.666	24.50	19.60	16.333	12.250	9.8	8.167	7.000	6.125	4.90
99.....	66.000	49.50	39.60	33.000	24.75	19.80	16.500	12.375	9.9	8.250	7.071	6.187	4.95

D.P. C.P.	1.5 2.094	2 1.571	2.5 1.257	3 1.047	4 0.785	5 0.628	6 0.524	8 0.393	10 0.3142	12 0.2618	14 0.2244	16 0.1963	20 0.1571
No. T													
100.....	66.666	50.00	40.00	33.333	25.00	20.00	16.666	12.500	10.0	8.333	7.142	6.250	5.00
101.....	67.333	50.50	40.40	33.666	25.25	20.20	16.835	12.625	10.1	8.416	7.214	6.312	5.05
102.....	68.000	51.00	40.80	34.000	25.50	20.40	17.000	12.750	10.2	8.500	7.285	6.375	5.10
103.....	68.666	51.50	41.20	34.333	25.75	20.60	17.166	12.875	10.3	8.583	7.357	6.437	5.15
104.....	69.333	52.00	41.60	34.666	26.00	20.80	17.333	13.000	10.4	8.666	7.428	6.500	5.20
105.....	70.000	52.50	42.00	35.000	26.25	21.00	17.500	13.125	10.5	8.750	7.500	6.562	5.25
106.....	70.666	53.00	42.40	35.333	26.50	21.20	17.666	13.250	10.6	8.833	7.571	6.625	5.30
107.....	71.333	53.50	42.80	35.666	26.75	21.40	17.833	13.375	10.7	8.916	7.642	6.687	5.35
108.....	72.000	54.00	43.20	36.000	27.00	21.60	18.000	13.500	10.8	9.000	7.714	6.750	5.40
109.....	72.666	54.50	43.60	36.333	27.25	21.80	18.166	13.625	10.9	9.083	7.785	6.812	5.45
110.....	73.333	55.00	44.00	36.666	27.50	22.00	18.333	13.750	11.0	9.167	7.857	6.875	5.50
111.....	74.000	55.50	44.40	37.000	27.75	22.20	18.500	13.875	11.1	9.250	7.928	6.937	5.55
112.....	74.666	56.00	44.80	37.333	28.00	22.40	18.666	14.000	11.2	9.333	8.000	7.000	5.60
113.....	75.333	56.50	45.20	37.666	28.25	22.60	18.833	14.125	11.3	9.416	8.071	7.062	5.65
114.....	76.000	57.00	45.60	38.000	28.50	22.80	19.000	14.250	11.4	9.500	8.142	7.125	5.70
115.....	76.666	57.50	46.00	38.333	28.75	23.00	19.166	14.375	11.5	9.583	8.214	7.187	5.75
116.....	77.333	58.00	46.40	38.666	29.00	23.20	19.333	14.500	11.6	9.666	9.285	7.250	5.80
117.....	78.000	58.50	46.80	39.000	29.25	23.40	19.500	14.625	11.7	9.750	8.357	7.312	5.85
118.....	78.666	59.00	47.20	39.333	29.50	23.60	19.666	14.750	11.8	9.833	8.428	7.375	5.90
119.....	79.333	59.50	47.60	39.666	29.75	23.80	19.833	14.875	11.9	9.916	8.500	7.437	5.95
120.....	80.000	60.00	48.00	40.000	30.00	24.00	20.000	15.000	12.0	10.000	8.571	7.500	6.00
121.....	80.666	60.50	48.40	40.333	30.25	24.20	20.166	15.125	12.1	10.083	8.642	7.562	6.05
122.....	81.333	61.00	48.80	40.666	30.50	24.40	20.333	15.250	12.2	10.167	8.714	7.625	6.10
123.....	82.000	61.50	49.20	41.000	30.75	24.60	20.500	15.375	12.3	10.250	8.785	7.687	6.15
124.....	82.666	62.00	49.60	41.333	31.00	24.80	20.666	15.500	12.4	10.333	8.857	7.750	6.20
125.....	83.333	62.50	50.00	41.666	31.25	25.00	20.833	15.625	12.5	10.416	8.928	7.812	6.25
126.....	84.000	63.00	50.40	42.000	31.50	25.20	21.000	15.750	12.6	10.500	9.000	7.875	6.30
127.....	84.666	63.50	50.80	42.333	31.75	25.40	21.166	15.875	12.7	10.583	9.071	7.937	6.35
128.....	85.333	64.00	51.20	42.666	32.00	25.60	21.333	16.000	12.8	10.666	9.142	8.000	6.40

B. & S. INVOLUTE GEAR TOOTH CUTTERS

No. 1 will cut wheels from 135 teeth to a rack.
No. 1½ will cut wheels from 80 teeth to 134 teeth.
No. 2 will cut wheels from 55 teeth to 134 teeth.
No. 2½ will cut wheels from 42 teeth to 54 teeth.
No. 3 will cut wheels from 35 teeth to 54 teeth.
No. 3½ will cut wheels from 30 teeth to 34 teeth.
No. 4 will cut wheels from 26 teeth to 34 teeth.
No. 4½ will cut wheels from 23 teeth to 25 teeth.
No. 5 will cut wheels from 21 teeth to 25 teeth.
No. 5½ will cut wheels from 19 teeth to 20 teeth.
No. 6 will cut wheels from 17 teeth to 20 teeth.
No. 6½ will cut wheels from 15 teeth to 16 teeth.
No. 7 will cut wheels from 14 teeth to 16 teeth.
No. 7½ will cut wheels from 13 teeth to 14 teeth.
No. 8 will cut wheels from 12 teeth to 13 teeth.

The eight cutters represented by the whole numbers constitute the regular set of cutters generally used for each pitch of tooth. The half numbers increase the set to 15 and give teeth which are theoretically more correct. In some work special cutters are used for each gear but the 15 cutters in a set offer all that most cases require.

TABLE SHOWING DEPTH OF SPACE AND THICKNESS OF TOOTH IN SPUR WHEELS, WHEN CUT WITH THESE CUTTERS

Pitch of Cutter	Depth to be cut in Gear Inches	Thickness of Tooth at Pitch Line. Inches	Pitch of Cutter	Depth to be cut in Gear Inches	Thickness of Tooth at Pitch Line. Inches
1½	1.726	1.257	11	.196	.143
1½	1.438	1.047	12	.180	.131
1½	1.233	.898	14	.154	.112
2	1.078	.785	16	.135	.098
2½	.958	.697	18	.120	.087
2½	.863	.628	20	.108	.079
2¾	.784	.570	22	.098	.071
3	.719	.523	24	.090	.065
3½	.616	.448	26	.083	.060
4	.539	.393	28	.077	.056
5	.431	.314	30	.072	.052
6	.359	.262	32	.067	.049
7	.308	.224	36	.060	.044
8	.270	.196	40	.054	.039
9	.240	.175	48	.045	.033
10	.216	.157			

BLOCK INDEXING IN CUTTING GEAR TEETH

Block or intermittent indexing is a method to increase the output of gear cutters by allowing the feed and cutting speed to be increased without unduly heating the work. This is done by jumping from the tooth just cut to a tooth far enough away to escape the local heating and on the following rounds to cut the intermediate teeth. While the indexing takes a trifle more time, the heat is distributed so that faster cutting can be done without heating and dulling the cutter.

The following table gives the indexing of gears from 25 to 200 teeth and is worked out for the Brown & Sharpe gear cutter but can be modified to suit other machines.

Teeth to be Cut	No. Indexed at Once	First Driver	First Follower	Second Driver	Second Follower	Turns of Locking Disc
25	4	100	50	72	30	4
26	3	100	50	90	52	4
27	2	100	50	90	54	4
28	3	100	50	90	56	4
29	3	100	50	90	58	4
30	1	100	50	90	60	2
31	3	100	50	90	62	4
32	3	100	50	90	64	4
33	4	100	50	80	44	4
34	3	100	50	90	68	4
35	4	100	50	96	56	4
36	5	100	48	80	40	4
37	5	100	30	90	74	4
38	5	100	30	90	76	4
39	5	100	30	90	78	4
40	3	100	50	90	80	4
41	5	100	30	90	82	4
42	5	100	30	90	84	4
43	5	100	30	90	86	4
44	5	100	30	90	88	4
45	7	100	50	70	30	4
46	5	100	30	90	92	4
47	5	100	30	90	94	4
48	5	100	30	90	96	4
49	5	100	30	90	98	4
50	7	100	50	84	40	4
51	4	100	30	96	68	2
52	5	100	50	90	52	2
53	7	100	50	90	54	2
54	5	100	50	90	56	2
55	7	100	50	90	58	2
56	5	100	50	90	60	2
57	4	100	50	90	62	2
58	5	100	50	90	64	2
59	7	100	50	90	66	2
60	5	100	50	90	68	2
61	7	100	50	90	70	2
62	5	100	50	90	72	2
63	7	100	50	90	74	2
64	5	100	50	90	76	2
65	7	100	50	90	78	2
66	5	100	50	90	80	2
67	7	100	50	90	82	2
68	5	100	50	90	84	2
69	7	100	50	90	86	2
70	7	100	50	90	88	2
71	7	100	50	90	90	2
72	5	100	50	90	92	2
73	7	100	50	90	94	2
74	5	100	50	90	96	2
75	7	100	50	90	98	2
76	5	100	50	84	40	2
77	7	100	50	84	42	2
78	5	100	50	84	44	2
79	7	100	50	84	46	2
80	5	100	50	84	48	2
81	7	100	50	84	50	2
82	5	100	50	84	52	2
83	7	100	50	84	54	2
84	5	100	50	84	56	2
85	4	100	50	84	58	2
86	5	100	30	90	52	2
87	7	100	30	90	54	2
88	5	100	30	90	56	2
89	7	100	30	90	58	2
90	7	100	30	90	60	2
91	3	100	30	96	76	2
92	5	100	30	90	62	2
93	7	100	30	84	40	2
94	5	100	30	90	64	2
95	4	100	30	80	56	2
96	5	100	30	90	66	2
97	7	100	30	90	68	2
98	5	100	30	90	70	2
99	10	100	30	80	44	2
100	7	100	50	84	40	2
101	7	100	30	70	52	2
102	5	100	30	60	68	2
103	7	100	50	60	90	2
104	5	100	30	70	60	2
105	4	100	30	70	56	2
106	7	100	30	70	60	2
107	7	100	30	70	62	2
108	7	100	30	70	64	2
109	7	100	30	70	66	2
110	7	100	50	84	44	2
111	5	100	74	80	40	2
112	5	100	60	90	56	2
113	7	100	30	84	76	2
114	7	100	30	84	76	2
115	8	100	50	96	46	2
116	5	100	60	90	58	2
117	8	100	30	96	78	2
118	7	100	70	72	68	2
119	3	100	50	70	40	2
120	7	100	50	70	40	2
121	4	60	66	96	44	2
122	7	100	50	84	44	2
123	7	100	50	84	46	2
124	5	100	50	84	48	2
125	7	100	50	84	50	2
126	5	100	50	84	52	2
127	7	100	50	84	54	2
128	5	100	50	84	56	2
129	7	100	50	84	58	2
130	7	100	50	84	60	2
131	7	100	50	84	62	2
132	5	100	50	84	64	2
133	4	100	70	96	76	2
134	5	100	50	90	67	2
135	7	100	50	84	54	2
136	5	100	50	80	68	2
137	5	100	50	84	40	2
138	5	100	92	80	40	2
139	3	50	50	80	70	2
140	5	100	88	80	40	2
141	5	100	94	80	40	2
142	6	90	66	96	52	2
143	6	90	66	90	52	2
144	5	100	60	90	72	2
145	6	100	50	72	58	2
146	5	100	98	80	40	2
147	5	100	60	90	74	2
148	5	100	60	90	74	2
149	5	100	60	84	50	2
150	7	100	60	84	50	2
151	5	100	60	90	76	2
152	5	100	60	90	76	2
153	5	100	68	80	60	2
154	5	100	56	72	66	2
155	6	100	50	72	62	2
156	5	100	60	90	78	2
157	7	100	50	84	64	2
158	5	100	50	84	64	2
159	6	100	50	84	66	2
160	7	100	50	84	66	2
161	5	100	70	60	46	2
162	7	100	60	84	52	2
163	5	100	60	90	82	2
164	5	100	60	90	82	2
165	7	100	50	84	66	2
166	5	100	60	90	84	2
167	7	100	50	84	68	2
168	5	100	60	90	84	2
169	6	96	52	90	78	2
170	7	100	50	84	68	2
171	5	70	42	80	76	2
172	5	100	60	90	86	2
173	7	100	60	84	58	2
174	7	100	60	90	88	2
175	8	100	50	96	70	2
176	5	100	60	90	88	2
177	7	100	60	70	50	2
178	9	90	56	96	52	2
179	5	100	60	90	92	2
180	5	100	60	90	92	2
181	6	100	60	90	94	2
182	7	100	60	84	68	2
183	5	100	60	90	96	2
184	5	100	60	90	96	2
185	6	100	50	72	74	2
186	7	100	60	84	62	2
187	5	100	44	48	68	2
188	5	100	60	90	94	2
189	5	100	60	80	84	2
190	7	100	50	84	76	2
192	5	100	60	90	96	2
195	7	100	50	84	78	2
196	5	100	60	90	98	2
198	7	100	50	70	66	2
200	7	60	60	80	84	2

THE DIMENSIONS OF GEARS BY METRIC PITCH

Module is the pitch diameter in mm. divided by the number of teeth in the gear.

Pitch diameter in mm. is the Module multiplied by the number of teeth in the gear.

M = Module.
D' = The pitch diameter of gear.
D = The whole diameter of gear.
N = The number of teeth in gear.
D'' = The working depth of teeth.
t = Thickness of teeth on pitch line.
f = Amount added to depth for clearance.

Then

$$M = \frac{D'}{N} \text{ or } \frac{D}{N+2}$$
$$D' = N\,M.$$
$$D = (N+2)\,M.$$
$$N = \frac{D'}{M} \text{ or } \frac{D}{M} - 2.$$
$$D'' = 2M.$$
$$t = M\ 1.5708.$$
$$f = \frac{\text{M } 1.5708}{10} = .157\ M.$$

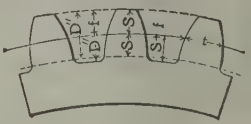


FIG. 5

The Module is equal to the part marked "S" in cut, measured in mm. and parts of mm.

Example: Module = 3.50 mm. 100 teeth.
Pitch diameter = 3.5 × 100 = 350 mm.
Whole diameter = (100 + 2) × 3.5 = 357 mm.

PITCHES COMMONLY USED—MODULE IN MILLIMETERS

Module	Corresponding English Diametral Pitch	Module	Corresponding English Diametral Pitch
½ mm.	50.800	4.5 mm.	5.644
¾	33.867	5	5.080
1	25.400	5.5	4.618
1.25	20.320	6	4.233
1.5	16.933	7	3.628
1.75	14.514	8	3.175
2	12.700	9	2.822
2.25	11.288	10	2.540
2.5	10.160	11	2.309
2.75	9.236	12	2.117
3	8.466	14	1.814
3.5	7.257	16	1.587
4	6.350		

MEASURING SPUR GEARS BY THE USE OF PINS

Spur-gear teeth may be accurately sized by placing pins or rolls between the teeth and measuring the distance over the pins with a micrometer. To avoid the necessity of calculating every measurement, the accompanying table has been worked out.

It will be noted that the same size of pin is used for the same pitch regardless of the number of teeth.

The sizes given in the accompanying tables are for gears of 1 diametral pitch, and since gears of 5, 7 and 10 pitch are $\frac{1}{5}$, $\frac{1}{7}$ and $\frac{1}{10}$ the size of one pitch, the size over pins will be $\frac{1}{5}$, $\frac{1}{7}$ or $\frac{1}{10}$ the size given in the table, provided a pin $\frac{1}{5}$, $\frac{1}{7}$ or $\frac{1}{10}$ the size used in calculating the table is used. The size pin used for 1 pitch is 1.750 inches; therefore the size pin to use for 5 pitch is 0.350 inch; for 7 pitch, 0.250 inch; for 10 pitch, 0.175 inch, and so forth.

As the number of teeth increase, the more nearly straight the teeth become. Between 10 and 12 teeth, in gears having 20-degree pressure angle, there is a difference of 2.000 parts of the pitch in the pitch diameter, while the difference over the pins in gears of $14\frac{1}{2}$-degree pressure angle is 2.021 parts of the pitch. Between 40 and 42 teeth, there is again a difference in pitch diameter of 2.000, while the difference over the pins between gears of 20- and $14\frac{1}{2}$-degree pressure angle is 2.004 parts of the pitch. Here the teeth become straight enough to jump from 42 to 52 teeth, then to 72, 102, 142, leaving the missing numbers to be found by interpolation.

For numbers of teeth above 142 and 143, add the even 2.000 parts of the pitch to the last figure given.

Example.—For a gear of 145 teeth, 10 pitch, $14\frac{1}{2}$-degree pressure angle. The size given in the table for 143 teeth is 145.618.

$$\frac{145.618 + 2.000}{10} = \text{size over pins for 145 teeth.}$$

The sizes given in the table are standard; that is, gears so cut will mesh at the proper center distances with no backlash. If 0.008-inch backlash is wanted, reduce each gear of the pair 0.008 inch.

To find size over pins, divide the figure in column under the pressure angle and opposite the number of teeth, by the pitch.

Example.—30 teeth, $\frac{7}{8}$ pitch, 20-degree pressure angle $\frac{32{,}488}{7} = 4.641$.

Note.—For those numbers of teeth missing, such as between 42 and 52, 73 and 103, etc., subtract the difference and add a proportionate part to the lesser figure. While this is not exactly correct, any error in the estimate will be divided by the pitch. An error of 0.001 becomes 0.0001 in the case of a 10-pitch gear; 0.0005 in a 5-pitch gear, and so forth.

TABLE FOR MEASUREMENTS OVER PINS, OF GEARS HAVING $14\frac{1}{2}$- AND 20-DEGREE PRESSURE ANGLES

Diam. over Pins, Even Teeth			Diam. of Pins Used		Diam. over Pins, Odd Teeth		
No. Teeth	Pressure Angle		Pitch	Size of Pin	No. of Teeth	Pressure Angle	
	$14\frac{1}{2}$ Degrees	20 Degrees				$14\frac{1}{2}$ Degrees	20 Degrees
10	12.415	12.413	1	1.7500	11	13.307	13.303
12	14.436	14.428	2	0.8750	13	15.346	15.335
14	16.455	16.440	3	0.5834	15	17.376	17.359
16	18.469	18.450	4	0.4375	17	19.400	19.378
18	20.482	20.458	5	0.3500	19	21.420	21.394
20	22.493	22.465	6	0.2917	21	23.437	23.407
22	24.502	24.471	7	0.2500	23	25.452	25.418
24	26.511	26.476	8	0.2188	25	27.464	27.428
26	28.519	28.480	9	0.1944	27	29.475	29.436
28	30.526	30.484	10	0.1750	29	31.485	31.443
30	32.532	32.488	12	0.1458	31	33.494	33.449
32	34.538	34.491	14	0.1250	33	35.502	35.454
34	36.543	36.494			35	37.509	37.459
36	38.548	38.497			37	39.516	39.463
38	40.552	40.499			39	41.522	41.467
40	42.556	42.501			41	43.527	43.471
42	44.560	44.503			43	45.533	45.475
52	54.576	54.512			53	55.553	55.487
72	74.596	74.521			73	75.580	75.504
102	104.613	104.529			103	105.602	105.517
142	144.627	144.535			143	145.618	145.526

A TABLE FOR DIMENSIONS FOR MITER GEARS

THE accompanying table is of service in determining the principal dimensions of miter gears (center angle 45 degrees), the number of teeth and the pitch being known. The table covers most of the possible number of teeth from 12 to 60, inclusive, and pitches from 2 to 10, inclusive, omitting 9. Values for face and cut angles correspond with designations in Fig. 6.

MITER GEARS. CENTER ANGLE 45 DEGREES

No. of Teeth	Pitch Diameters										Outside Diameters										Face Angle	Cut Angle
	2 P.	3 P.	4 P.	5 P.	6 P.	7 P.	8 P.	10P.	2 P.	3 P.	4 P.	5 P.	6 P.	7 P.	8 P.	10P		
12	6	4	3	2 2/5	2	1 5/7	1 1/2	1 1/5	6.71	4.48	3.35	2.68	2.24	1.92	1.68	1.34	51°43′	37°14′
13	6 1/2	4 1/3	3 1/4	2 3/5	2 1/6	1 6/7	1 5/8	1 3/10	7.21	4.80	3.60	2.88	2.40	2.06	1.81	1.44	51°12′	37°40′
14	7	4 2/3	3 1/2	2 4/5	2 1/3	2	1 3/4	1 2/5	7.71	5.14	3.85	3.08	2.57	2.20	1.93	1.54	50°47′	38°20′
15	7 1/2	5	3 3/4	3	2 1/2	2 1/7	1 7/8	1 1/2	8.21	5.46	4.10	3.28	2.73	2.35	2.06	1.64	50°23′	38°46′
16	8	5 1/3	4	3 1/5	2 2/3	2 2/7	2	1 3/5	8.71	5.80	4.35	3.48	2.90	2.49	2.18	1.74	50°03′	39°00′
17	8 1/2	5 2/3	4 1/4	3 2/5	2 5/6	2 3/7	2 1/8	1 7/10	9.21	6.14	4.60	3.68	3.07	2.63	2.31	1.84	49°45′	39°30′
18	9	6	4 1/2	3 3/5	3	2 4/7	2 1/4	1 4/5	9.71	6.48	4.85	3.88	3.24	2.77	2.43	1.94	49°29′	39°48′
19	9 1/2	6 1/3	4 3/4	3 4/5	3 1/6	2 5/7	2 3/8	1 9/10	10.21	6.80	5.10	4.08	3.40	2.92	2.56	2.04	49°15′	40°04′
20	10	6 2/3	5	4	3 1/3	2 6/7	2 1/2	2	10.71	7.14	5.35	4.28	3.57	3.06	2.68	2.14	49°03′	40°19′
21	10 1/2	7	5 1/4	4 1/5	3 1/2	3	2 5/8	2 1/10	11.21	7.46	5.60	4.48	3.73	3.20	2.81	2.24	48°51′	40°32′
22	11	7 1/3	5 1/2	4 2/5	3 2/3	3 1/7	2 3/4	2 1/5	11.71	7.80	5.85	4.68	3.90	3.35	2.93	2.34	48°41′	40°45′
23	11 1/2	7 2/3	5 3/4	4 3/5	3 5/6	3 2/7	2 7/8	2 3/10	12.21	8.14	6.10	4.88	4.07	3.49	3.00	2.44	48°31′	40°56′
24	12	8	6	4 4/5	4	3 3/7	3	2 2/5	12.71	8.48	6.35	5.08	4.24	3.63	3.18	2.54	48°22′	41°06′
25	12 1/2	8 1/3	6 1/4	5	4 1/6	3 4/7	3 1/8	2 1/2	13.21	8.80	6.60	5.28	4.40	3.77	3.31	2.64	48°14′	41°15′
26	13	8 2/3	6 1/2	5 1/5	4 1/3	3 5/7	3 1/4	2 3/5	13.71	9.14	6.85	5.48	4.57	3.92	3.43	2.74	48°07′	41°24′
27	13 1/2	9	6 3/4	5 2/5	4 1/2	3 6/7	3 3/8	2 7/10	14.21	9.46	7.10	5.68	4.73	4.06	3.56	2.84	48°00′	41°32′
28	14	9 1/3	7	5 3/5	4 2/3	4	3 1/2	2 4/5	14.71	9.80	7.35	5.88	4.90	4.20	3.68	2.94	47°54′	41°39′
29	14 1/2	9 2/3	7 1/4	5 4/5	4 5/6	4 1/7	3 5/8	2 9/10	15.21	10.14	7.60	6.08	5.07	4.35	3.81	3.04	47°47′	41°46′
30	15	10	7 1/2	6	5	4 2/7	3 3/4	3	15.71	10.48	7.85	6.28	5.24	4.49	3.93	3.14	47°42′	41°53′
31	15 1/2	10 1/3	7 3/4	6 1/5	5 1/6	4 3/7	3 7/8	3 1/10	16.21	10.80	8.10	6.48	5.40	4.63	4.06	3.24	47°37′	41°59′
32	16	10 2/3	8	6 2/5	5 1/3	4 4/7	4	3 1/5	16.71	11.14	8.35	6.68	5.57	4.77	4.18	3.34	47°32′	42°04′
33	16 1/2	11	8 1/4	6 3/5	5 1/2	4 5/7	4 1/8	3 3/10	17.21	11.46	8.60	6.88	5.73	4.92	4.31	3.44	47°27′	42°10′
34	17	11 1/3	8 1/2	6 4/5	5 2/3	4 6/7	4 1/4	3 2/5	17.71	11.80	8.85	7.08	5.90	5.06	4.43	3.54	47°23′	42°15′
35	17 1/2	11 2/3	8 3/4	7	5 5/6	5	4 3/8	3 1/2	18.21	12.14	9.10	7.28	6.07	5.20	4.56	3.64	47°19′	42°19′
36	18	12	9	7 1/5	6	5 1/7	4 1/2	3 3/5	18.71	12.48	9.35	7.48	6.24	5.35	4.68	3.74	47°15′	42°24′
37	18 1/2	12 1/3	9 1/4	7 2/5	6 1/6	5 2/7	4 5/8	3 7/10	19.21	12.80	9.60	7.68	6.40	5.49	4.81	3.84	47°11′	42°28′
38	19	12 2/3	9 1/2	7 3/5	6 1/3	5 3/7	4 3/4	3 4/5	19.71	13.14	9.85	7.88	6.57	5.63	4.93	3.94	47°08′	42°32′
40	20	13 1/3	10	8	6 2/3	5 5/7	5	4	20.71	13.80	10.35	8.28	6.90	5.92	5.18	4.14	47°01′	42°39′
42	21	14	10 1/2	8 2/5	7	6	5 1/4	4 1/5	21.71	14.48	10.85	8.68	7.24	6.20	5.43	4.34	46°56′	42°46′
44	22	14 2/3	11	8 4/5	7 1/3	6 2/7	5 1/2	4 2/5	22.71	15.14	11.35	9.08	7.57	6.49	5.68	4.54	46°50′	42°52′
46	23	15 1/3	11 1/2	9 1/5	7 2/3	6 4/7	5 3/4	4 3/5	23.71	15.80	11.85	9.48	7.90	6.77	5.93	4.74	46°46′	42°58′
48	24	16	12	9 3/5	8	6 6/7	6	4 4/5	24.71	16.48	12.35	9.88	8.24	7.06	6.18	4.94	46°42′	43°06′
50	25	16 2/3	12 1/2	10	8 1/3	7 1/7	6 1/4	5	25.71	17.14	12.85	10.28	8.57	7.35	6.43	5.14	46°37′	43°12′
54	27	18	13 1/2	10 4/5	9	7 5/7	6 3/4	5 2/5	27.71	18.48	13.85	11.08	9.24	7.92	6.93	5.54	46°31′	43°18′
58	29	19 1/3	14 1/2	11 3/5	9 2/3	8 2/7	7 1/4	5 4/5	29.71	19.80	14.85	11.88	9.90	8.49	7.43	5.94	46°24′	43°24′
60	30	20	15	12	10	8 4/7	7 1/2	6	30.71	20.48	15.35	12.28	10.24	8.77	7.68	6.14	46°21′	43°30′

BEVEL GEARS

Bevel Gears are used to transmit power when shafts are not parallel. They can be made for any angle, but are more often at right angles than any other. Right angle bevel gears having the same number of teeth are often called miter gears. The teeth are or should be radial so that they are longer at the outer end. The names of parts are shown in Fig. 6. These should be noted carefully, particularly the face angles. The earlier editions measured *face angle* at right angles to the axis, but this is now changed as shown.

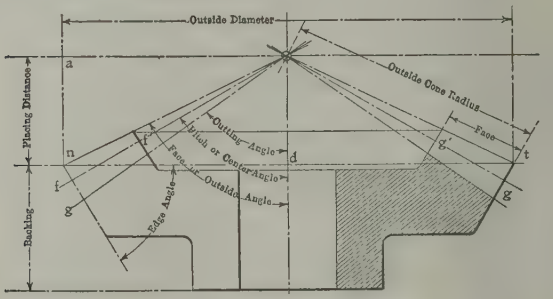


Fig. 6.—Bevel Gear Parts

LAYING OUT BEVEL GEAR BLANKS

In laying out bevel gears, first decide upon the pitch, and draw the center lines *B B* and *C C*, intersecting at right angles at *A* as shown in Fig. 7. Then draw the lines *D D* to *E E* the same distance each side of *B B* and parallel to it; the distance from *D D* to *E E* being as many eighths of an inch—if it be 8 pitch—as there are to be teeth in the gear. In the example the number of teeth is 24; therefore the distance from *D D* to *E E* will be $2\frac{4}{8}$, or $1\frac{1}{2}$ inches each side of *B B*. *K K* and *L L* are similarly drawn, but there being only 16 teeth in the small gear, the distance from *K K* to *L L* will be $1\frac{6}{8}$, or 1 inch each side of *C C*. Then through the intersections of *D D* and *L L*, *E E* and *L L*, and *E E* and *K K*, draw the diagonals *F A*. These are the pitch lines. Through the same point draw lines as *G G* at right angles to the pitch lines, forming the backs of the teeth. On these lines lay off $\frac{1}{8}$ of an inch each side of the pitch lines, and draw *M A* and *N A*, forming the faces and bottoms of the teeth. The lines *H H* are drawn parallel to *G G*, the distance between them being the width of the face.

The face of the larger gear should be turned to the lines *M A*, and the small gear to *N A*. For other pitches the same rules apply. If 4 pitch, use 4ths instead of 8ths; if 3 pitch, 3ds, and so on.

Bevel gears should always be turned to the exact diameters and angles of the drawings and the teeth cut at the correct angle.

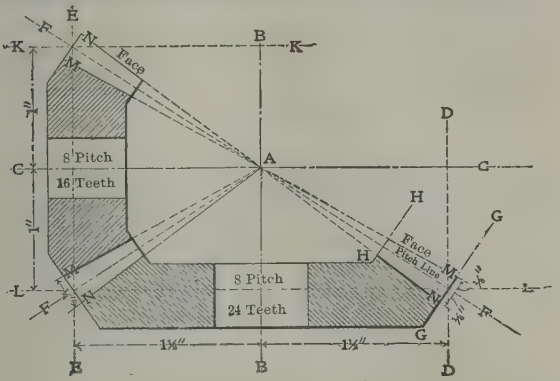


FIG. 7.—Laying Out Bevel Gears

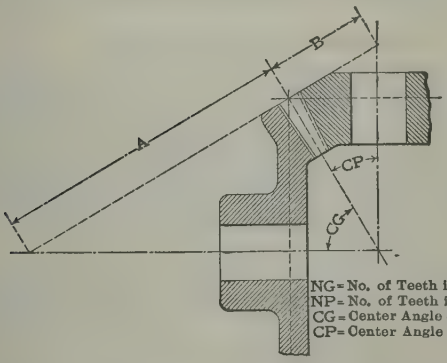


FIG. 8.—Finding the Cutter to Use

Proportions of Miter and Bevel Gears

To Find the Pitch or Center Angle:

Divide the number of teeth in the gear by the number of teeth in the pinion. This gives the tangent of the pitch angle of the gear. Or divide the number of teeth in the pinion by the teeth in the gear and get the tangent of the pitch angle of the pinion. Subtracting either pitch angle from 90 gives the pitch angle of the other.

To Find the Outside Diameter:

Multiply the cosine of the pitch angle by twice the addendum and add the pitch diameter.

To Find the Outside Cone Radius or Apex Distance:

Multiply the secant of the pitch angle of the pinion by ½ the pitch diameter of the gear.

To Find the Face and Cutting Angles:

Divide the addendum by the outside cone radius or apex distance. This gives the tangent of the addendum or outside angle. Subtract this angle from the pitch angle of the pinion to obtain the cutting angle of the pinion, and the face angle of the gear. Subtract the same addendum angle from the center angle of the gear to obtain the cutting angle of the gear and the face angle of the pinion. This gives a uniform clearance and is especially for use with rotary cutters.

To Find Height of Addendum at Small End of Tooth:

Divide the addendum at the large end of the tooth by the outside cone radius. This gives the decrease in height of the addendum for each inch of gear face. Multiply this by the length of the gear face and subtract the result from the addendum of the large end of the tooth. The difference is the height of the addendum at the small end of the tooth.

CUTTERS FOR BEVEL GEARS

Lay out the bevel gears and draw lines A and B at right angles to the center angle line. Extend this to the center lines and measure A and B. The distance A = the *radius* of a spur gear of the same pitch, and finding the number of teeth in such a gear we have the right cutter for the bevel gear in question. If the gears are 8 pitch and the distance A = 4 inches, multiply these together, and by 2 to get the diameter. Then $2 \times 4 \times 8 = 64$ teeth, so that a No. 2 cutter is the one to use. For the pinion, if B is 2 inches, then $2 \times 2 \times 8 = 32$ or a No. 4 cutter is the one to use.

Setting Cutter Out of Center

The cutter can be no thicker than the space at the small end of the teeth, so it is necessary to set it out of center and rotate the blank to make the space right at the large end of the teeth. The amount of this set-over can be found by the following rule and table of the Brown & Sharpe Mfg. Co.

Divide distance A, Fig. 8, by the width of the face. Find the factor in table for this ratio and the cutter to be used. Divide this factor by the diametral pitch and subtract the quotient from half the thickness of the cutter at the pitch line. As a formula this is:

$$\text{Set-over} = \frac{Tc}{2} - \frac{\text{factor in table}}{P}.$$

Tc = thickness of cutter used at pitch line.
P = diametral pitch of gear to be cut.

EXAMPLE.—A bevel gear of 24 teeth, 6 pitch, 30-degree pitch cone angle and $1\frac{1}{4}$-inch face. This gear calls for a No. 4 cutter and apex distance A is 4 inches. Apex $4 \div 1\frac{1}{4} = 3.2$: 1 or about $3\frac{1}{4}$:1. The table factor for this ratio with No. 4 cutter is 0.280. To measure the cutter at the pitch line, find depth of space below the pitch line, or $S + f$ on page 190. On this cutter the thickness will be found to be 0.1745. The amount of set-over then is:

$$\frac{0.1745}{2} - \frac{0.280}{6} = 0.0406. \text{ inch.}$$

First set cutter central with spiral head. Set head to proper cutting angle. Set dial on cross-feed to zero. Index and cut two or three grooves to depth. Set cutter out of center 0.04 inch and note adjustment on cross-feed dial. Rotate gear in opposite direction to setover until side of cutter nearest center line cuts entire surface of teeth. Reverse this for other side and measure teeth at both ends. If teeth at large end are two thick when small end is correct, increase setover. If small end is too thick, when large end is right, decrease the set-over. Adjust accordingly.

TABLE FOR OBTAINING SET-OVER FOR CUTTING BEVEL GEARS

$$\text{Ratio of Apex Distance to Width of Face} = \frac{\text{Apex}}{\text{Face}}$$

No. of Cutter	.3 1	$3\frac{1}{4}$ 1	$3\frac{1}{2}$ 1	$3\frac{3}{4}$ 1	4 1	$4\frac{1}{4}$ 1	$4\frac{1}{2}$ 1	$4\frac{3}{4}$ 1	5 1	$5\frac{1}{2}$ 1	6 1	7 1	8 1
1	0.254	0.254	0.255	0.256	0.257	0.257	0.257	0.258	0.258	0.259	0.260	0.262	0.264
2	0.266	0.268	0.271	0.272	0.273	0.274	0.274	0.275	0.277	0.279	0.280	0.283	0.284
3	0.266	0.268	0.271	0.273	0.275	0.278	0.280	0.282	0.283	0.286	0.287	0.290	0.292
4	0.275	0.280	0.285	0.287	0.291	0.293	0.296	0.298	0.298	0.302	0.305	0.308	0.311
5	0.280	0.285	0.290	0.293	0.295	0.296	0.298	0.300	0.302	0.307	0.309	0.313	0.315
6	0.311	0.318	0.323	0.328	0.330	0.331	0.337	0.340	0.343	0.348	0.352	0.356	0.362
7	0.289	0.298	0.308	0.316	0.324	0 329	0.334	0.338	0.343	0.350	0.360	0.370	0.376
8	0.275	0.286	0.296	0.300	0.310	0.331	0.338	0.344	0.352	0.361	0.368	0.380	0.386

USING THE BEVEL GEAR TABLE

TAKE a pair of bevel gears 24 and 72 teeth, 8 diametral pitch. Divide the pinion by the gear — $24 \div 72 = .3333$. This is the tangent of the center angle of pinion. Look in the seven columns under center angles for the nearest number to this. The nearest is .3346 in the center column, as all these are decimals to four places. Follow this out to the left and find 18 in the center angle column. As the .3346 is in the column marked .50 the center angle of the pinion is 18.50 degrees. Looking to the right under center angles

for gears find 71 and add the .50 making the gear angle 71.50 degrees. Thus:

Center angle of pinion 18.5 degrees.
Center angle of gear 71.5 degrees.

In the first column opposite 18 is 36. Divide this by the number of teeth in the pinion, 24, and get 1.5 degrees. This is the angle increase for this pair of gears, and is the amount to be added to the center angle to get the face angle and to be deducted to get the cut angles. This gives

Pinion center angle 18.5 + 1.5 = 20 degrees face angle.
Pinion center angle 18.5 − 1.5 = 17 degrees cut angle.
Gear center angle 71.5 + 1.5 = 73 degrees face angle.
Gear center angle 71.5 − 1.5 = 70 degrees cut angle.

For the outside diameter go to the column of diameter increase and in line with 18 find 1.90. Divide this by the pitch, 8, and get .237, which is the diameter increase for the pinion. Follow the same line to the right and find .65 for the gear increase. Divide this by the pitch, .8, and get .081 for gear increase. This gives

Pinion, 24 teeth, 8 pitch = 3 inches + .237 = 3.237 in. outside dia.

Gear, 72 teeth, 8 pitch = 9 inches + .081 = 9.081 in. outside dia.

To Select the Cutter

Another way of selecting the cutter is to divide the number of teeth in the gear by the cosine of the center angle C and the answer is the number of teeth in a spur gear from which to select the cutter. For the pinion the process is the same except the number of teeth in the pinion is divided by the sine of the center angle. Formula

$$\text{Tangent of } CG = \frac{NG}{NP}. \qquad \text{Tangent of } CP = \frac{NP}{NG}$$

$$\text{Number of teeth to use in selecting cutter for gear} = \frac{NG}{Cos\ CG}.$$

$$\text{Number of teeth to use in selecting cutter for pinion} = \frac{NP}{Sin\ CG}.$$

Any pair of gears can be figured out in the same way, bearing in mind, when finding the center angle for the gear, to read the parts of a degree from the decimals at the bottom, and for the pinion, to read them from the top. In the example worked out the tangent came in the center column so that it made no difference. If, however, the tangent had been .3476 we read the pinion angle at the top, 19.17 degrees, and the gear angle at the bottom, 70.83. By noting that the sum of the two angles is 90 degrees, we can be sure we are right.

Bevel Gear Table

SHAFT ANGLES 90°

Angle Increase; Divide by Teeth in Pinion	Diameter Increase; Divide by Pitch for Pinion	Center Angle Degrees for Pinion	Center Angle Hundredth Degrees — Left-hand Column read here: 0	.17	.33	.50	.67	.83	1.00	Center Angle Degrees for Gear	Diameter Increase; Divide by Pitch for Gear
1	2.00	0	.0000	.0029	.0058	.0087	.0116	.0145	.0175	89	.03
2	2.00	1	.0175	.0204	.0233	.0262	.0291	.0320	.0349	88	.07
4	2.00	2	.0349	.0378	.0407	.0437	.0466	.0495	.0524	87	.10
6	2.00	3	.0524	.0553	.0582	.0612	.0641	.0670	.0699	86	.14
8	1.99	4	.0699	.0729	.0758	.0787	.0816	.0846	.0875	85	.17
10	1.99	5	.0875	.0904	.0934	.0963	.0992	.1022	.1051	84	.21
12	1.99	6	.1051	.1080	.1110	.1139	.1169	.1198	.1228	83	.24
14	1.98	7	.1228	.1257	.1278	.1317	.1346	.1376	.1405	82	.28
16	1.98	8	.1405	.1435	.1465	.1495	.1524	.1554	.1584	81	.31
18	1.98	9	.1584	.1614	.1644	.1673	.1703	.1733	.1763	80	.34
20	1.97	10	.1763	.1793	.1823	.1853	.1883	.1914	.1944	79	.38
22	1.96	11	.1944	.1974	.2004	.2035	.2065	.2095	.2126	78	.41
24	1.96	12	.2126	.2156	.2186	.2217	.2247	.2278	.2309	77	.45
26	1.95	13	.2309	.2339	.2370	.2401	.2432	.2462	.2493	76	.48
28	1.94	14	.2493	.2524	.2555	.2586	.2617	.2648	.2679	75	.51
30	1.93	15	.2679	.2711	.2742	.2773	.2805	.2836	.2867	74	.55
32	1.92	16	.2867	.2899	.2931	.2962	.2994	.3026	.3057	73	.58
34	1.91	17	.3057	.3089	.3121	.3153	.3185	.3217	.3249	72	.62
36	1.90	18	.3249	.3281	.3314	.3346	.3378	.3411	.3443	71	.65
37	1.89	19	.3443	.3476	.3508	.3541	.3574	.3607	.3640	70	.68
39	1.88	20	.3640	.3673	.3706	.3739	.3772	.3805	.3839	69	.71
41	1.86	21	.3839	.3872	.3906	.3939	.3973	.4006	.4040	68	.75
43	1.85	22	.4040	.4074	.4108	.4142	.4176	.4210	.4245	67	.78
45	1.84	23	.4245	.4279	.4314	.4348	.4383	.4417	.4452	66	.81
47	1.82	24	.4452	.4487	.4522	.4557	.4592	.4628	.4663	65	.84
49	1.81	25	.4663	.4699	.4734	.4770	.4806	.4841	.4877	64	.88
50	1.79	26	.4877	.4913	.4950	.4986	.5022	.5059	.5095	63	.91
52	1.78	27	.5095	.5132	.5169	.5206	.5243	.5280	.5317	62	.93
54	1.76	28	.5317	.5354	.5392	.5430	.5467	.5505	.5543	61	.97
56	1.74	29	.5543	.5581	.5619	.5658	.5696	.5735	.5774	60	1.00
57	1.73	30	.5774	.5812	.5851	.5890	.5930	.5969	.6009	59	1.03
59	1.71	31	.6009	.6048	.6088	.6128	.6168	.6208	.6249	58	1.05
61	1.69	32	.6249	.6289	.6330	.6371	.6412	.6453	.6494	57	1.08
63	1.67	33	.6494	.6536	.6577	.6619	.6661	.6703	.6745	56	1.11
64	1.65	34	.6745	.6787	.6830	.6873	.6916	.6959	.7002	55	1.14
66	1.63	35	.7002	.7046	.7089	.7133	.7177	.7221	.7265	54	1.17
68	1.61	36	.7265	.7310	.7355	.7400	.7445	.7490	.7536	53	1.20
69	1.59	37	.7536	.7581	.7627	.7673	.7720	.7766	.7813	52	1.23
71	1.57	38	.7813	.7860	.7907	.7954	.8002	.8050	.8098	51	1.25
72	1.55	39	.8098	.8146	.8195	.8243	.8292	.8342	.8391	50	1.28
73	1.53	40	.8391	.8441	.8491	.8541	.8591	.8642	.8693	49	1.31
75	1.51	41	.8693	.8744	.8796	.8847	.8899	.8952	.9004	48	1.33
77	1.48	42	.9004	.9057	.9110	.9163	.9217	.9271	.9325	47	1.36
79	1.46	43	.9325	.9380	.9435	.9490	.9545	.9601	.9657	46	1.39
80	1.43	44	.9657	.9713	.9770	.9827	.9884	.9942	1.0000	45	1.41
81	1.41	45	1.0000	1.0058	1.0117	1.0176	1.0235	1.0295	1.0355	44	1.43
			1.00	.83	.67	.50	.33	.17	0		

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SPIRAL GEARS

THE term spiral gear is usually applied to gears having angular teeth and which do not have their shafts or axis in parallel lines, and usually at right angles. Spiral gears take the place of bevel gears and give a smoother action as well as allowing greater speed ratios in a given space. When gears with angular or skew teeth run on parallel shafts, they are usually called helical gears.

THE CALCULATION OF FORTY-FIVE DEGREE SPIRAL GEARS

Pitch of Cutter	Pitch Diam.	Pitch of Spiral in Inches to One Turn	No. of Teeth in Spur Same Curvature	Outside Diam.	Thickness of Tooth at Pitch Line (Normal)	Depth of Tooth	Clearance	Circular Pitch (Normal)
	Multiply by Number of Teeth in Spiral Gear			Add to P.D.				
2	0.70710	2.22142	2.828	1.0000	0.7854	1.0785	0.0785	1.5708
2¼	0.62855	1.97464	2.828	0.8888	0.6981	0.9587	0.0699	1.3963
2½	0.56566	1.77707	2.828	0.8000	0.6283	0.8628	0.0628	1.2566
2¾	0.51425	1.61556	2.828	0.7273	0.5712	0.7844	0.0572	1.1424
3	0.47140	1.48094	2.828	0.6666	0.5236	0.7190	0.0524	1.0472
3½	0.40406	1.26939	2.828	0.5714	0.4488	0.6163	0.0449	0.8976
4	0.35355	1.11071	2.828	0.5000	0.3927	0.5393	0.0393	0.7854
5	0.28283	0.88853	2.828	0.4000	0.3142	0.4314	0.0314	0.6283
6	0.23570	0.74047	2.828	0.3333	0.2618	0.3595	0.0202	0.5236
7	0.20203	0.63469	2.828	0.2857	0.2244	0.3081	0.0224	0.4488
8	0.17677	0.55534	2.828	0.2500	0.1963	0.2696	0.0196	0.3927
9	0.15714	0.49367	2.828	0.2222	0.1745	0.2397	0.0175	0.3491
10	0.14143	0.44431	2.828	0.2000	0.1571	0.2157	0.0157	0.3142
11	0.12856	0.40388	2.828	0.1818	0.1428	0.1961	0.0143	0.2856
12	0.11785	0.37024	2.828	0.1666	0.1309	0.1798	0.0131	0.2618
14	0.10101	0.31733	2.828	0.1429	0.1122	0.1541	0.0112	0.2244
16	0.08836	0.27759	2.828	0.1250	0.0982	0.1348	0.0098	0.1963
18	0.07855	0.24677	2.828	0.1111	0.0873	0.1198	0.0088	0.1745
20	0.07071	0.22214	2.828	0.1000	0.0785	0.1079	0.0079	0.1571
22	0.06428	0.20194	2.828	0.0909	0.0714	0.0980	0.0071	0.1428
24	0.05892	0.18510	2.828	0.0833	0.0654	0.0898	0.0065	0.1309
26	0.05437	0.17081	2.828	0.0769	0.0604	0.0829	0.0060	0.1208
28	0.05050	0.15865	2.828	0.0714	0.0561	0.0770	0.0056	0.1122
30	0.04713	0.14806	2.828	0.0666	0.0524	0.0719	0.0053	0.1047
32	0.04425	0.13901	2.828	0.0625	0.0491	0.0674	0.0050	0.0982
36	0.03929	0.12343	2.828	0.0555	0.0436	0.0599	0.0043	0.0785
40	0.03533	0.11099	2.828	0.0500	0.0393	0.0539	0.0039	0.0873
48	0.02944	0.09249	2.828	0.0417	0.0327	0.0449	0.0033	0.0654

In considering speed ratios for spiral gears the driving gear can be taken as a worm having as many threads as there are teeth and the driven as the worm wheel with its number of teeth, so that one revolution of the driver will turn a point on the pitch circle of the driven gear as many inches as the lead of the teeth of the driver. Divide this by the circumference of the pitch circle of the driven gear to get the revolutions of the driven.

While the subject of spiral gears is rather complex if considered broadly, most of the difficulties disappear when they have a tooth angle of 45 degrees. It is perhaps for this reason that from 75 to 90 per cent. of the spiral gears used are made with this angle.

This has the added advantage of being the most durable, although there is but a trifling increase in wear down to 30 degrees and the wear at 20 degrees is not serious. In cases of necessity even 12 degrees can be used without destructive wear.

Where higher speed ratios than can be had with a 45-degree angle tooth are necessary, they can be laid out as will be shown later and can be cut on most milling machines. The usual change gears allow about two thousand different spirals to be cut.

Where the angles are not 45 degrees, the gear with the greatest angle must always be the driver.

All of the tooth parts are derived from the normal pitch while the pitch diameters are derived from the circular pitch. These are never the same in two gears of a pair except when both are 45 degrees.

As the diameter of a spiral gear does not indicate its speed ratio, the terms *driver* and *follower* are used in place of gear and pinion.

45-DEGREE SPIRAL GEAR

These gears are the simplest of all spirals to lay out and to make, the required speed ratios being obtained by varying the diameters, precisely as with spur or bevel gears, the rules for the speed ratio being the same in both cases. Moreover, the various factors required in laying out and making such gears can be reduced to the simple table shown.

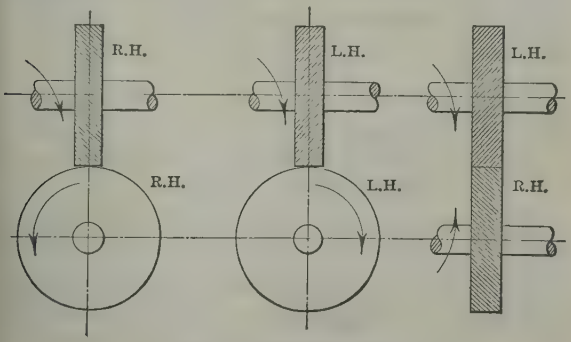


FIG. 9.—Diagrams of 45-deg. Spiral Gears

Such a table has been worked out by E. J. Kearney. With it any one can quickly make the few calculations connected with any pair of 45-degree gears having teeth between 2 and 48 diametral pitch. This table will be found on preceding page:

Example

Let it be desired to construct a pair of spiral gears with 35 teeth in the gear and 16 teeth in the pinion, using a 10-pitch cutter. Using table on page 200, we have for a 10-pitch cutter, under the proper columns,

Pitch diameter = $0.14143 \times 35 = 4.950$.
Outside diameter = $4.950 + 0.200 = 5.150$
Pitch in inches to one turn of spiral = $0.44431 \times 35 = 15.550$.

Note.—A slight variation in one turn makes no practical difference, hence the ordinary change gears furnished with a universal miller will usually be found sufficient.

Number of teeth in spur with same curvature = $2.828 \times 35 = 98.980$.

Looking at B. & S. spur-gear cutter list, we see that 99 is between 55 and 134; therefore we select a No. 2 cutter.

In a similar manner using 16 as a multiplier we obtain the data for the pinion. This gives 2.262 as pitch diameter, so that the center distance = $\frac{4.950 + 2.262}{2} = 3.606$.

The various dimensions follow:

	Gear	Pinion
Number of teeth	35	16
Pitch diameter	4.950	2.262
Outside diameter	5.150	2.462
Pitch in inches to one turn	15.550	7.108
Angle of spiral	45°	45°
Pitch of cutter	10	10
Number of cutter	2	3
Whole depth of tooth	0.216	0.216
Angle of shafts	90°	
Center distance of shafts	3.606	

FIGURING SPIRAL GEARS

As there is no direct solution for a pair of spiral gears, their calculation is a tedious process and the result must be found by trial.

As numerous calculations are absolutely necessary, this formula should not involve division by large or fractional numbers and should contain the fewest possible operations. Such formulas are:

Let

C = Center distance,
P = Diametral pitch,
N_1 = Number of teeth in the driver,
N_2 = Number of teeth in the follower,
S_1 = Spiral angle of driver,
S_2 = Spiral angle of follower.

Then,

$$2C = \frac{(Secant\ S_1\ N_1) + (Secant\ S_2\ N_2)}{P}.$$

That is, the sum of the secant of the driving angle times the number of teeth in the driver, and the secant of the follower angle times the number of teeth in it divided by the diametral pitch equals twice the center distance. This formula is derived as follows: The secant of the spiral angle times the pitch diameter of a spur gear of the same number of teeth and pitch equals the pitch diameter of a spiral gear of that angle, the pitch of the spur gear being the same as the normal pitch of the spiral gear. Now for a spur gear the number of teeth divided by the diametral pitch equals the pitch diameter. Therefore, *the secant of the spiral angle* $\times \frac{N}{P}$ = *the pitch diameter of a spiral gear*. The combined pitch diameters times the center distance are equal to

$$\left(Secant\ S_1 \times \frac{N_1}{P.}\right) + \left(Secant\ S_2 \times \frac{N_2}{P.}\right)$$

or (*secant* $S_1\ N_1$) + (*secant* $S_2\ N_2$) for one diametral pitch.

The quantity *secant* $S_1 N_1$ is the pitch diameter for the driver and *secant* $S_2\ N_2$ is the pitch diameter of the follower. To obtain the center distance for any other pitch, it is simply necessary to divide this last result by that pitch.

A table of secants will furnish constants covering the entire range of angles; and therefore, all possible solutions for a pair of gears. After long experience in calculating spiral gears these are recommended by C. H. Logue as the best and simplest for all cases.

Points to Be Kept in Mind When Calculating Spiral Gears

To assist in their use the following points should be kept in mind:

1. The diameter of a spiral gear increases with its angle.

2. Therefore, the diameter of the follower will reduce as the driving angle is increased, although not necessarily in the same ratio.

3. It is quite possible for the center distance to remain practically constant through quite a range of angles, the follower decreasing as the driver is increased. This is especially true when the gear having the greater number of teeth is the driver.

4. If the center distance is too great when the driving angle is 45 degrees—it must not go below that in any case—a lower number of teeth must be selected for both driver and follower, while maintaining the same ratio, and another trial made using a much higher angle for the driver.

5. The center distance will increase with the angle of the driver. This increase is more rapid when reducing than when increasing the speed of the follower. This refers to parallel shafts.

6. The number of teeth selected for each trial must be in proportion to the desired ratio.

7. Forty-five degrees is commonly accepted as the most efficient driving angle.

Selecting Secants and Trial Numbers of Teeth

To calculate a pair of spiral gears, select secants for the desired angles, assuming the normal pitch, try out the value of 2 C with trial numbers of teeth for driver and follower.

If the value 2 C is too small increase the number of teeth and try again. A very few calculations will show the number of teeth to secure the closest result.

If the center distance thus found is not as desired the angles must be shifted, keeping in mind the general laws governing the change of the center distance with the angle.

It is often found that when the desired center distance is reached the driving angle is too large to be desirable. The only alternative is to change the normal pitch and try again. A slide rule will give approximate results.

When there are limitations placed on the diameter of one or both of the gears the following formula is of value. It may also serve as a check on the above calculations. The pitch diameters are assumed.

$$Tan.\ S_1 = \frac{\left(\begin{matrix}Pitch\ diameter\ of\ driver \times \\ number\ of\ revolutions\ of\ driver\end{matrix}\right)}{\left(\begin{matrix}Pitch\ diameter\ of\ follower \times \\ number\ of\ revolutions\ of\ follower\end{matrix}\right)}.$$

This will set a limit on the driving angle S_1, to exceed which means that the gear will be too large.

REAL PITCHES FOR CIRCULAR PITCH SPIRAL GEARS

THE accompanying table will be found convenient in figuring particulars for spiral gearing, as it eliminates much of the work by shortening the process, thus making it quite an easy and simple matter to find the dimensions for either helical gears with axes parallel to each other or for gears with right-angle drive.

Formulas for use with the table are as follows: Circumference on pitch line = real pitch multiplied by number of teeth.

Lead of spiral = Circumference on pitch line divided by the tangent.

Pitch diameter = Circumference divided by 3.1416.

For whole diameter add the same amount above pitch line as for spur wheels of the same pitch as the normal pitch.

The following is an example of the use of the table: A pair of wheels is required to be: Ratio, 6 to 1; normal pitch, 1 in.; driver, 6 teeth; follower, 36 teeth; angle for driver, 66 degrees; angle for follower, 24 degrees.

Referring to the table we find that the real pitch for the driver is 2.4585.

2.4585 × 6 (*teeth*) = 14.751 (*circumference on pitch line*).
Cir. 14.751 ÷ 2.246 (*tangent*) = 6.567 (*lead of spiral*).
Cir. 14.751 ÷ 3.1416 = 4.695 (*pitch diameter*).
For the follower the real pitch is 1.0946.
1.0946 × 36 = 39.4056 (*circumference*).
Cir. 39.4056 ÷ 0.4452 (*tangent*) = 88.512 (*lead of spiral*).
Cir. 39.4056 ÷ 3.1416 = 12.543 (*pitch diameter*).

Angles from Axis		Normal Pitches													
		1/4"		5/16"		3/8"		7/16"		1/2"		5/8"		3/4"	
Driver	Follower	Driver	Follower	Driver	Follower	Driver	Follower	Driver	Follower	Driver	Follower	Driver	Follower	Driver	Follower
80°	10°	1.4396	0.2538	1.7996	0.3173	2.1595	0.3808	2.5194	0.4442	2.8793	0.5077	3.5992	0.6346	4.3190	0.7616
79°	11°	1.3102	0.2546	1.6377	0.3183	1.9653	0.3820	2.2928	0.4457	2.6304	0.5093	3.2755	0.6366	3.9306	0.7640
78°	12°	1.2024	0.2556	1.5030	0.3195	1.8036	0.3833	2.1042	0.4473	2.4049	0.5112	3.0060	0.6390	3.6072	0.7666
77°	13°	1.1113	0.2565	1.3892	0.3207	1.6669	0.3848	1.9449	0.4490	2.2226	0.5131	2.7784	0.6414	3.3338	0.7696
76°	14°	1.0334	0.2576	1.2917	0.3220	1.5500	0.3865	1.8084	0.4509	2.0668	0.5153	2.5834	0.6440	3.1000	0.7730
75°	15°	0.9659	0.2591	1.2074	0.3238	1.4489	0.3885	1.6903	0.4529	1.9318	0.5181	2.4148	0.6476	2.8978	0.7772
74°	16°	0.9069	0.2600	1.1337	0.3250	1.3605	0.3901	1.5872	0.4551	1.8139	0.5201	2.2674	0.6502	2.7210	0.7802
73°	17°	0.8550	0.2614	1.0688	0.3268	1.2826	0.3931	1.4964	0.4575	1.7101	0.5228	2.1377	0.6536	2.5652	0.7842
72°	18°	0.8090	0.2628	1.0112	0.3286	1.2135	0.3943	1.4157	0.4600	1 6180	0.5257	2.0225	0.6572	2.4270	0.7886
71°	19°	0.7678	0.2644	0.9598	0.3305	1.1518	0.3966	1.3438	0.4627	1.5357	0.5288	1.9196	0.6610	2.3036	0.7032
70°	20°	0.7309	0.2660	0.9137	0.3325	1.0964	0.3990	1.2791	0.4656	1.4619	0.5320	1.8274	0.6651	2.1928	0 7981
69°	21°	0.6976	0.2678	0.8720	0.3347	1.0464	0.4017	1.2208	0.4686	1.3952	0.5356	1.7440	0.6694	2.0928	0.8034
68°	22°	0.6673	0.2696	0.8342	0.3370	1.0010	0.4044	1.1679	0.4718	1.3346	0.5392	1.6684	0.6740	2.0020	0.8088
67°	23°	0.6398	0.2716	0.7998	0.3395	0.9597	0.4074	1.1120	0.4752	1.2796	0.5432	1.5996	0.6790	1.9194	0.8148
66°	24°	0.6146	0.2736	0.7683	0.3420	0.9220	0.4105	1.0756	0.4789	1.2292	0.5472	1.5366	0.6841	1.8440	0.8210
65°	25°	0.5915	0.2758	0.7394	0.3448	0.8873	0.4137	1.0352	0.4827	1.1830	0.5516	1.4788	0.6896	1.7746	0.8274
64°	26°	0.5702	0.2781	0.7129	0.3477	0.8554	0.4172	0.9930	0.4868	1.1406	0.5563	1.4258	0.6954	1.7108	0.8344
63°	27°	0.5507	0.2806	0.6883	0.3507	0.8260	0.4209	0.9636	0.4910	1.1014	0.5012	1.3766	0.7014	1.6520	0.8418
62°	28°	0.5325	0.2831	0.6656	0.3539	0.7988	0.4247	0.9319	0.4955	1.0650	0.5662	1.3312	0.7078	1.5976	0.8494
61°	29°	0.5157	0.2858	0.6446	0.3573	0.7735	0.4287	0.9024	0.5002	1.0314	0.5716	1.2892	0.7146	1.5470	0.8574
60°	30°	0.5000	0.2886	0.6250	0.3608	0.7500	0.4330	0.8750	0.5051	1.0000	0.5773	1.2500	0.7216	1.5000	0.8660
59°	31°	0.4853	0.2916	0.6067	0.3646	0.7281	0.4375	0.8494	0.5104	0.9708	0.5833	1.2134	0.7292	1.4562	0.8750
58°	32°	0.4717	0.2948	0.5897	0.3685	0.7076	0.4422	0.8256	0.5159	0.9435	0.5896	1.1794	0.7370	1.4152	0.8844
57°	33°	0.4590	0.2981	0.5738	0.3726	0.6885	0.4471	0.8033	0.5216	0.9180	0.5962	1.1476	0.7452	1.3770	0.8942
56°	34°	0.4470	0.3015	0.5588	0.3769	0.6706	0.4523	0.7824	0.5277	0.8941	0.6031	1.1176	0.7538	1.3412	0.9046
55°	35°	0.4358	0.3052	0.5448	0.3815	0.6538	0.4578	0.7627	0.5341	0.8717	0.6104	1.0896	0.7630	1.3076	0.9156
54°	36°	0.4253	0.3090	0.5316	0.3862	0.6380	0.4635	0.7443	0.5408	0.8506	0.6180	1.0632	0.7724	1.2760	0.9270
53°	37°	0.4154	0.3130	0.5192	0.3913	0.6231	0.4695	0.7269	0.5478	0.8308	0.6260	1.0384	0.7826	1.2462	0.9390
52°	38°	0.4060	0.3172	0.5076	0.3965	0.6091	0.4759	0.7161	0.5552	0.8121	0.6345	1.0152	0.7930	1.2182	0.9518
51°	39°	0.3972	0.3217	0.4965	0.4021	0.5959	0.4825	0.6952	0.5628	0.7945	0.6434	0.9930	0.8042	1.1918	0.9650
50°	40°	0.3889	0.3264	0.4861	0.4079	0.5834	0.4895	0.6806	0.5711	0.7778	0.6527	0.9722	0.8159	1.1668	0.9790
49°	41°	0.3810	0.3312	0.4763	0.4140	0.5716	0.4969	0.6668	0.5797	0.7621	0.6625	0.9526	0.8280	1.1432	0.9938
48°	42°	0.3736	0.3364	0.4670	0.4205	0.5604	0.5046	0.6538	0.5887	0.7472	0.6728	0.9340	0.8410	1.1208	1.0092
47°	43°	0.3665	0.3418	0.4582	0.4272	0.5498	0.5127	0.6415	0.5982	0.7331	0.6836	0.9164	0.8544	1.0996	1.0254
46°	44°	0.3598	0.3475	0.4498	0.4344	0.5398	0.5213	0.6298	0.6082	0.7197	0.6950	0.8996	0.8688	1.0796	1.0426
45°	45°	0.3536	0.3536	0.4419	0.4419	0.5303	0.5303	0.6187	0.6187	0.7071	0.7071	0.8839	0.8839	1.0606	1.0606

TABLE OF REAL PITCHES FOR CIRCULAR PITCH SPIRAL GEARS. *(Continued)*

Angles from Axis		Normal Pitches												Tangent of Angle	
		⅞″		1″		1¼″		1½″		1¾″		1½″			
Driver	Follower	Driver	Follower	Driver	Follower	Driver	Follower	Driver	Follower	Driver	Follower	Driver	Follower	Driver	Follower
80°	10°	5.0388	0.8884	5.7587	1.0154	6.4785	1.1423	7.1983	1.2692	7.8192	1.3062	8.6380	1.5230	5.6713	0.1763
79°	11°	4.5856	0.8914	5.2407	1.0187	5.8961	1.1460	6.5510	1.2732	7.2061	1.4007	7.8612	1.5280	5.1446	0.1944
78°	12°	4.2084	0.8946	4.8098	1.0223	5.4109	1.1501	6.0122	1.2780	6.6134	1.4057	7.2146	1.5335	4.7046	0.2126
77°	13°	3.8898	0.8980	4.4454	1.0263	5.0001	1.1546	5.5568	1.2828	6.1125	1.4111	6.6681	1.5394	4.3315	0.2309
76°	14°	3.6168	0.9018	4.1336	1.0306	4.6500	1.1594	5.1669	1.2882	5.6837	1.4171	6.2004	1.5459	4.0108	0.2493
75°	15°	3.3806	0.9058	3.8637	1.0353	4.3466	1.1658	4.8296	1.2952	5.3126	1.4248	5.7955	1.5543	3.7321	0.2679
74°	16°	3.1744	0.9102	3.6279	1.0403	4.0814	1.1703	4.5348	1.3004	4.9884	1.4304	5.4419	1.5604	3.4874	0.2867
73°	17°	2.9928	0.9150	3.4203	1.0457	3.8478	1.1764	4.2754	1.3071	4.7029	1.4378	5.1304	1.5685	3.2709	0.3057
72°	18°	2.8314	0.9200	3.2360	1.0515	3.6405	1.1829	4.0450	1.3143	4.4495	1.4457	4.8540	1.5771	3.0777	0.3249
71°	19°	2.6876	0.9254	3.0715	1.0576	3.4554	1.1898	3.8394	1.3220	4.2233	1.4542	4.6072	1.5864	2.9042	0.3443
70°	20°	2.5582	0.9312	2.9238	1.0641	3.2892	1.1972	3.6548	1.3302	4.0202	1.4632	4.3857	1.5962	2.7475	0.3640
69°	21°	2.4416	0.9372	2.7904	1.0711	3.1391	1.2050	3.4880	1.3389	3.8368	1.4728	4.1856	1.6067	2.6051	0.3839
68°	22°	2.3358	0.9436	2.6694	1.0785	3.0030	1.2133	3.3369	1.3480	3.6705	1.4829	4.0041	1.6178	2.4751	0.4040
67°	23°	2.2240	0.9504	2.5503	1.0863	2.8792	1.2221	3.1991	1.3580	3.5190	1.4937	3.8389	1.6295	2.3559	0.4245
66°	24°	2.1512	0.9578	2.4585	1.0946	2.7659	1.2314	3.0732	1.3682	3.3805	1.5051	3.6876	1.6418	2.2460	0.4452
65°	25°	2.0704	0.9654	2.3662	1.1033	2.6619	1.2412	2.9577	1.3792	3.2535	1.5171	3.5493	1.6550	2.1445	0.4663
64°	26°	1.9960	0.9736	2.2811	1.1127	2.5663	1.2517	2.8515	1.3908	3.1366	1.5298	3.4218	1.6689	2.0503	0.4877
63°	27°	1.9272	0.9820	2.2026	1.1223	2.4780	1.2626	2.7533	1.4029	3.0287	1.5431	3.3040	1.6835	1.9626	0.5095
62°	28°	1.8638	0.9910	2.1300	1.1326	2.3963	1.2741	2.6625	1.4157	2.9288	1.5572	3.1950	1.6988	1.8807	0.5317
61°	29°	1.8048	1.0004	2.0626	1.1433	2.3205	1.2862	2.5783	1.4292	2.8361	1.5721	3.0940	1.7150	1.8040	0.5543
60°	30°	1.7500	1.0102	2.0000	1.1548	2.2500	1.2990	2.5000	1.4433	2.7500	1.5877	3.0000	1.7320	1.7321	0.5774
59°	31°	1.6988	1.0208	1.9415	1.1667	2.1843	1.3125	2.4269	1.4583	2.6696	1.6042	2.9134	1.7499	1.6643	0.6009
58°	32°	1.6512	1.0318	1.8870	1.1790	2.1229	1.3266	2.3588	1.4740	2.5947	1.6213	2.8306	1.7687	1.6003	0.6249
57°	33°	1.6066	1.0432	1.8360	1.1923	2.0655	1.3414	2.2951	1.4904	2.5246	1.6395	2.7451	1.7885	1.5399	0.6494
56°	34°	1.5648	1.0554	1.7883	1.2062	2.0118	1.3569	2.2353	1.5077	2.4589	1.6585	2.6824	1.8093	1.4826	0.6745
55°	35°	1.5254	1.0682	1.7434	1.2207	1.9614	1.3734	2.1793	1.5260	2.3972	1.6786	2.6151	1.8311	1.4281	0.7002
54°	36°	1.4886	1.0816	1.7012	1.2360	1.9139	1.3905	2.1266	1.5449	2.3392	1.6997	2.5519	1.8541	1.3764	0.7265
53°	37°	1.4538	1.0956	1.6614	1.2521	1.8693	1.4086	2.0770	1.5652	2.2847	1.7217	2.4924	1.8781	1.3270	0.7536
52°	38°	1.4322	1.1104	1.6242	1.2690	1.8273	1.4276	2.0303	1.5862	2.2333	1.7449	2.4364	1.9035	1.2799	0.7813
51°	39°	1.3904	1.1256	1.5890	1.2867	1.7876	1.4476	1.9862	1.6084	2.1847	1.7693	2.3835	1.9301	1.2349	0.8098
50°	40°	1.3612	1.1422	1.5557	1.3054	1.7502	1.4686	1.9446	1.6317	2.1391	1.7949	2.3336	1.9581	1.1918	0.8391
49°	41°	1.3336	1.1594	1.5240	1.3250	1.7148	1.4906	1.9054	1.6562	2.0958	1.8219	2.2863	1.9875	1.1504	0.8093
48°	42°	1.3076	1.1774	1.4944	1.3456	1.6813	1.5138	1.8681	1.6820	2.0549	1.8502	2.2417	2.0184	1.1106	0.9004
47°	43°	1.2830	1.1964	1.4662	1.3673	1.6495	1.5382	1.8328	1.7089	2.0161	1.8001	2.1994	2.0510	1.0724	0.9325
46°	44°	1.2596	1.2164	1.4395	1.3901	1.6194	1.5639	1.7994	1.7377	1.9792	1.9114	2.1593	2.0852	1.0355	0.9657
45°	45°	1.2374	1.2374	1.4142	1.4142	1.5910	1.5910	1.7678	1.7678	1.9445	1.9445	2.1213	2.1213	1.0000	1.0000

Another method of finding the lead of spiral is to multiply the real pitch by the number of teeth, but for this purpose take the real pitch of the mating wheel.

In the above example we should have

Real pitch of follower, $1.0946 \times 6 = 6.5676$ (*lead of spiral*).

Real pitch of driver, $2.4585 \times 36 = 88.506$.

It will be noticed that there is a slight difference in the result but this is unimportant, as it is only brought about by the dropping of a few decimal points in the tangent.

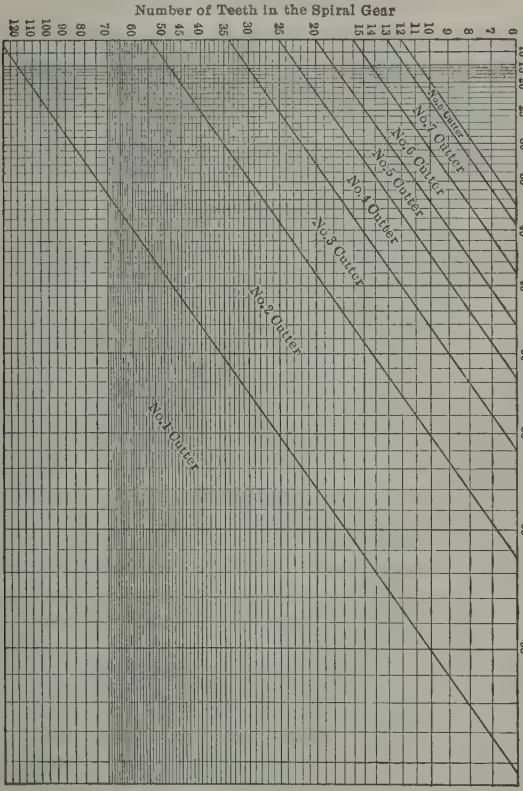


FIG. 10.—Chart for Selecting Spiral Gear Cutters

SPUR-GEAR CUTTERS FOR SPIRAL GEARS

To find the number of a spur-gear cutter to be used in cutting a given spiral gear, locate the intersection of lines traced from the points representing the number of teeth and the spiral angle on the two scales. The number in the area on the chart within which the intersection falls is the cutter number of Brown & Sharpe's involute cutter system required.

TO FIND SPIRAL ANGLE OF OLD GEAR

FIND normal circular pitch by measuring whole depth of tooth and thickness at pitch line. Subtract twice the addendum to get pitch diameter. Multiply P.D. by 3.1416 and divide by number of teeth to get real circular pitch. Divide normal circular pitch by real circular pitch which gives cosine of spiral angle on which gear is cut.

To get the lead, multiply circumference by co-tangent of spiral angle, or divide by tangent.

SPIRAL GEAR TABLE

WHILE it is better in every case to understand the principles involved before using tables as this tends to prevent errors, they can be used with good results by simply following directions carefully. The subject of spiral gears is so much more complicated than other gears that many will prefer to depend entirely on the tables.

This table gives the circular pitch and addendum or the diametral pitch and lead of spirals for one diametral pitch and with teeth having angles of from 1 to 89 degrees to 45 and 45 degrees. For other pitches divide the addendum given and the spiral number by the required pitch and multiply the results by the required number of teeth. This will give the pitch diameter and lead of spiral for each wheel. For the outside diameter add two diametral pitches as in spur gearing.

Suppose we want a pair of spiral gears with 10 and 80 degree angles, 8 diametral pitch cutter, with 16 teeth in the small gear, having 10-degree angle and 10 teeth in the large gear with its 80-degree angle.

Find the 10-degree angle of spiral and in the third column find 1.0154. Divide by pitch, 8, and get .1269. Multiply this by number of teeth $-$ $.1269 \times 16 = 2.030$ = pitch diameter. Add 2 pitches $-$ two $\frac{1}{8} = \frac{1}{4}$ and $2.030 + .25 = 2.28$ inches outside diameter.

The lead of spiral for 10 degrees for small wheel is 18.092. Divide by pitch $= 18.092 \div 8 = 2.2615$. Multiply by number of teeth, $2.2615 \times 16 = 36.18$, the lead of spiral, which means that it makes one turn in 36.18 inches.

For the other gear with its 80-degree angle, find the addendum, 5.7587. Divide by pitch, 8, $= .7198$. Multiply by number of teeth, $10 = 7.198$. Add two pitches, or .25, gives 7.448 as outside diameter.

SPIRAL GEAR TABLE

SHAFT ANGLES 90° FOR ONE DIAMETRAL PITCH

Angle of Spiral Degrees	To obtain the circular pitch for one tooth, divide by the required diametral pitch	To obtain the pitch diameter, divide by the required diametral pitch and multiply the quotient by the required number of teeth	To obtain the lead of spiral, divide by the required diametral pitch and multiply quotient by the required number of teeth	To obtain the pitch diameter, divide by the required diametral pitch and multiply the quotient by the required number of teeth	To obtain the circular pitch for one tooth, divide by the required diametral pitch.	Angle of Spiral in Degrees
	Circular Pitch	One Tooth or Addend.	Lead of Spirals	One Tooth or Addendum	Circular Pitch	
Small Wheel	Small Wheel	Small Wheel	Small Wheel	Large Wheel	Large Wheel	Large Wheel	Large Wheel
1	3.1419	1.0001	180.05	3.1420	57.298	180.01	89
2	3.1435	1.0006	90.020	3.1435	28.653	90.016	88
3	3.1457	1.0013	60.032	3.1458	19.107	60.026	87
4	3.1491	1.0024	45.038	3.1492	14.335	45.035	86
5	3.1535	1.0038	37.077	3.1527	11.473	36.044	85
6	3.1589	1.0055	30.056	3.1589	9.5667	30.055	84
7	3.1652	1.0075	25.728	3.1651	8.2055	25.778	83
8	3.1724	1.0098	22.573	3.1724	7.1852	22.573	82
9	3.1806	1.0124	20.082	3.1807	6.3924	20.082	81
10	3.1900	1.0154	18.092	3.1901	5.7587	18.092	80
11	3.2003	1.0187	16.464	3.2003	5.2408	16.464	79
12	3.2145	1.0232	15.076	3.2105	4.8097	15.104	78
13	3.2242	1.0263	13.966	3.2294	4.4454	13 988	77
14	3.2377	1.0306	12.986	3.2378	4.1335	12.986	76
15	3.2522	1.0352	12.138	3.2524	3.8637	12.138	75
16	3.2679	1.0402	11.393	3.2678	3.6279	11.397	74
17	3.2848	1.0456	10.417	3.2821	3.4203	10.745	73
18	3.3116	1.0514	10.192	3.3032	3.2360	10.166	72
19	3.3225	1.0576	9.6494	3.3225	3.0715	9.6494	71
20	3.3430	1.0641	9.1848	3.3433	2.9238	9.1854	70
21	3.3650	1.0711	8.7662	3.3652	2.7904	8.7663	69
22	3.3882	1.0785	8.3862	3.3833	2.6694	8.3862	68
23	3.4127	1.0863	8.0399	3.4129	2.5593	8.0403	67
24	3.4451	1.0946	7.7379	3.4391	2.4585	7.7242	66
25	3.4661	1.1033	7.4332	3.4663	2.3662	7.4336	65
26	3.4953	1.1126	7.1664	3.4952	2.2811	7.1663	64
27	3.5258	1.1223	6.9108	3.5257	2.2026	6.9197	63
28	3.5579	1.1325	6.6912	3.5575	2.1300	6.6916	62
29	3.5918	1.1433	6.4799	3.5919	2.0626	6.4799	61
30	3.6276	1.1547	6.2778	3.6277	2.0000	6.2832	60
31	3.6650	1.1666	6.0979	3.6652	1.9416	6.0997	59
32	3.7043	1.1791	5.9282	3.7044	1.8870	5.9282	58
33	3.7457	1.1923	5.7710	3.7459	1.8360	5.7680	57
34	3.7894	1.2062	5.6181	3.7826	1.7882	5.6178	56
35	3.8349	1.2207	5.4754	3.8351	1.7434	5.4770	55
36	3.8830	1.2360	5.3431	3.8834	1.7013	5.3448	54
37	3.9336	1.2521	5.2201	3.9261	1.6616	5.2200	53
38	3.9867	1.2690	5.1028	3.9921	1.6242	5.1026	52
39	4.0482	1.2867	4.9866	4.0416	1.5890	4.9920	51
40	4.1019	1.3054	4.8873	4.1012	1.5557	4.8874	50
41	4.1626	1.3250	4.7885	4.1540	1.5242	4.7884	49
42	4.2273	1.3456	4.6949	4.2272	1.4944	4.6048	48
43	4.2956	1.3673	4.6065	4.2956	1.4662	4.6062	47
44	4.3671	1.3901	4.5223	4.3675	1.4395	4.5225	46
45	4.4428	1.4142	4.4428	4.4428	1.4142	4.4428	45

The lead of spiral is 3.1901. Dividing by pitch, 8 = .3988. Multiplying by number of teeth = 3.988 the lead of spiral.

When racks are to mesh with spiral gears, divide the number in the circular pitch columns for the given angle by the required diametral pitch to get the corresponding circular pitch.

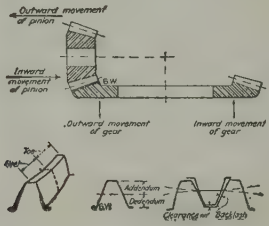
If we want to make a rack to mesh with a 40-degree spiral gear of 8 pitch: Look for circular pitch opposite 40 and find 4.101. Dividing by 8 gives .512 as the circular pitch for this angle. The greater the angle the greater the circular or linear pitch, as can be seen by trying an 80-degree angle. Here the circular pitch is 2.261 inches.

TESTING AND ADJUSTING SPIRAL BEVEL GEAR DRIVES

(By Permission the Gleason Works, Rochester, N. Y.)

THE proper adjustment of bevel gears in assembly is a vital factor in obtaining quiet and durable gears.

There are two distinct considerations in obtaining the proper tooth contact; one is the bearing along the tooth, lengthwise bearing, the other the bearing up and down the tooth, or profile bearing, and it is essential that the two be considered separately to obtain the proper results in combination. Diagram shows definition.



Graphic definitions of the terms used in describing the proper procedure to mount a pair of bevel gears are given herewith.

Bevel gears are cut with a predetermined amount of backlash to suit the pitch and operating conditions, and this backlash should not be altered by any great amount to obtain the proper tooth contact, as the necessity of such a step indicates a fault either in the cutting or in the alignment of the supporting bearings. The usual amount of blacklash is from 0.004 inch on 8-pitch gears to 0.012 inch on 3-pitch.

Bevel gears mounted in a rigid testing machine should show a bearing toward the small end of the tooth and the amount the bearing favors the small end is determined experimentally by the stiffness of the mounting in which the gears are to be finally assem-

bled. Any spring in the mounting of the gears under load will cause the bearing to move toward the large end, and in no case should the bearing be heaviest at the large end of the tooth under the operating load. Any extra load, such as induced by suddenly applying the full load, will cause the bearing to become concentrated on the top corner of the large end of the tooth and breakage will ensue. The figures below show typical tooth bearings as obtained in a testing machine and when mounted in an automobile axle, also the effect of spring in the mounting on the apexes of the gear and pinion. It will be observed that the apexes do not coincide when the gear mounting has sprung under the working load. Therefore, when cutting the gears, it is necessary to make provision for this lift or spring.

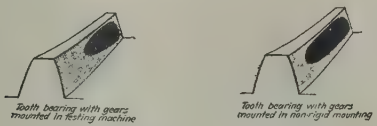


FIG. 11.—Effect of Mounting

Bevel gears are commonly cut to run flush at the large end of the teeth and, as a first step, they should be so assembled in the mounting for an initial trial. Powdered red lead and any light machine oil should be mixed and spread over the working surfaces of the teeth with a brush, to show clearly the tooth contact obtained.

There is no difference in the method of adjusting spiral or straight bevels, and, while the following statements are particularly applicable for spiral bevels, they are also true for straight bevels.

After mounting the gears flush with the proper amount of backlash, they should be operated under load in each direction for a minute. In the automobile rear axle driving gears, the rear axle should first be raised to have the wheels clear the floor, then the motor started and the wheels driven in both directions with the brakes applied to obtain the necessary load.

All figures show the bearing on the gear tooth. With a right-hand spiral bevel gear (mating with a left-hand spiral pinion) mounted in an automobile, the driving side is on the convex side of the tooth and the concave side of the tooth is used when in reverse.

The tooth bearing, both lengthwise and profile, should appear as shown in A and B Fig. 12, but a condition of tooth contact may be obtained, as indicated in C to N. The lengthwise bearing adjustments will first be considered.

Figs. 3 and 4 show what is called a cross-bearing and is caused by either a misalignment of the mounting or an error in the cutting. The mounting should be tested and, if found faulty, should be corrected. If the drive side has a toe bearing and the reverse a heel bearing, the gears are serviceable, provided the bearing is about five-eighths of the tooth length, but if the heel bearing occurs on the drive side, it should not be used and the cutting conditions should be altered if the mounting is found correct.

Figs. 5 and 6 show a toe bearing on each side of the tooth and the gear must be moved away from the pinion to increase the lengthwise bearing, which, on ratios 1:1 to approximately 4:1, will change the profile bearing to some extent and an adjustment of the pinion may be required. This movement of the gear will introduce more backlash and the gear cutting should be changed in order to properly locate the bearing if this increase in backlash becomes excessive.

Figs. 7 and 8 show a heel bearing on both sides and the gear must be adjusted towards the pinion to increase the lengthwise bearing, which, on ratios 1:1 to approximately 4:1, will change the profile bearing to some extent and an adjustment of the pinion may be required.

Figs. 9 and 10 show a low bearing on gear tooth which may appear at any position along the tooth. The pinion should be moved away from the gear, and on ratios 1:1 to approximately 4:1 the gear should be moved towards the pinion to maintain the proper backlash. This movement of the gear will alter the lengthwise bearing and several adjustments for both lengthwise and profile bearing may be required to obtain the proper tooth bearing.

Figs. 11 and 12 show a high bearing on gear tooth which may appear at any position along the tooth. The pinion should be moved towards the gear, and on ratios 1:1 to approximately 4:1, the gear should be moved away from the pinion to maintain the backlash. This movement of the gear will alter the lengthwise bearing and several adjustments for both lengthwise and profile bearing may be required.

Figs. 13 and 14 show a lame bearing. It is possible to adjust the gears and obtain a fair driving condition, as indicated in Fig. 1, but a poor coast or reverse, and the only method of completely eliminating the trouble is to cut the gears properly.

It must be borne in mind that the adjustment cited should be moderate, and if great amounts of adjustments are needed the mounting and gear cutting must be carefully checked, and the necessary steps taken to correct trouble in the making of the gears or mounting.

TOLERANCES IN GEARING

The following tolerances were proposed by Harry Horsington, ordnance engineer at Rock Island Arsenal in 1925. It is suggested that a very flexible feeler be used as a "no-go" gage in testing backlash in spur gears.

It should be remembered that manufacturing tolerances of gages must be considered, which will reduce the actual component or work tolerance. It will be observed that in the tables shown the clearances between the shafts have not been considered. Allowance has been made in the tables for close work and so that the necessary oil film in the bearing will absorb part of the essential bearing clearance and the remainder will take care of the tolerances in the gages. It should also be remembered that these tables are for production work and that closer fits may be secured by special fitting or selective assembly.

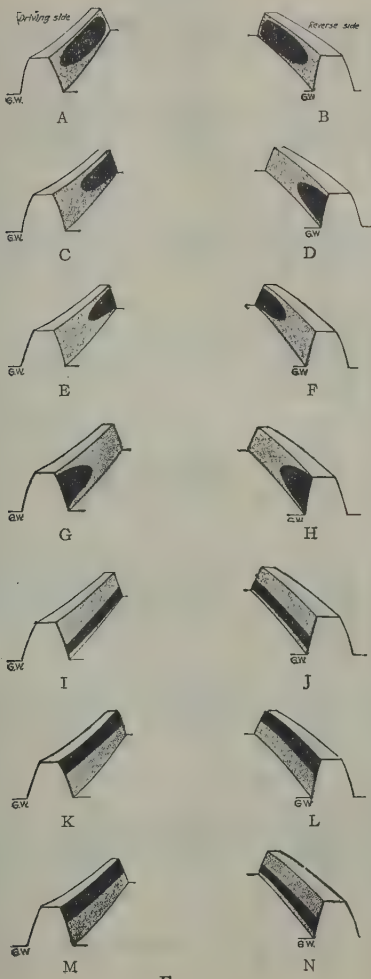


FIG. 12

TABLE 1.—PROPOSED TOLERANCES FOR SPUR GEARS AND SUPPORTS

Twenty-degree involute, closest practical work on production basis, presupposing high speed, hardened and ground gears or accurately cut gears.

Diameter Pitch	Running Clearance Expressed as Backlash	Allowable Variation in Each Gear	Maximum Amount Each Tooth Space is Widened, Including Half Clearance	Necessary Allowed Variation in Center Distance	Backlash Resulting from Maximum Center Distance	Greatest Allowable Backlash in Pair, Assembled	Allowable Variation from Theoretical Center Distance of One Gear and Correct Master Rack
2	0.004	+0.0025	+0.0045	+0.003	0.0022	0.012	−0.0027−−0.0061
2.5	0.004	0.0025	0.0045	0.00275	0.0020	0.011	0.0027− 0.0061
3	0.003	0.0025	0.004	0.00275	0.0020	0.010	0.0021− 0.0055
3.5	0.0025	0.00235	0.0036	0.0025	0.0018	0.009	0.0017− 0.005
4	0.002	0.0022	0.0032	0.0025	0.0018	0.008	0.0014− 0.0044
5	0.002	0.0016	0.0026	0.0025	0.0018	0.007	0.0014− 0.0036
6	0.0015	0.0015	0.00225	0.0025	0.0018	0.0065	0.001 − 0.0031
7	0.0015	0.0015	0.00225	0.002	0.0015	0.006	0.001 − 0.0031
8	0.001	0.0015	0.002	0.002	0.0015	0.0055	0.0007− 0.0027
9	0.001	0.0015	0.002	0.0015	0.0011	0.005	0.0007− 0.0027
10	0.0008	0.0015	0.0019	0.001	0.0007	0.0045	0.0005− 0.0026
12	0.0008	0.001	0.0014	0.001	0.0007	0.004	0.0005− 0.002
14–18	0.0006	0.001	0.0013	0.001	0.0007	0.0033	0.0015
20	0.0004	0.001	0.0012	0.001	0.0006	0.003	0.0015

TABLE 2.—PROPOSED TOLERANCES FOR SPUR GEARS AND SUPPORTS

Twenty-degree involute, ordinary conditions with cut gears—not hardened. Good center distance fixtures. Assembling without fitting or selection. Suitable for gun-carriage elevating and traversing-gear trains.

Diameter Pitch	Running Clearance Expressed as Backlash. In Pair	Allowable Variation in Width of Space. Either Gear	Maximum Amount Each Tooth Space is Widened, Including Clearance in Column 2	Necessary Allowed Variation in Center Distance of Shaft	Backlash Resulting from Maximum Center Distance	Greatest Resulting Backlash in Pair, Assembled	Allowable Variation from Theoretical Center Distance of One Gear and Correct Master Rack
2	0.010	0.0028	+0.0078	+0.007	0.0051	0.021	−0.0069−−0.0107
2.5	0.0075	0.0025	0.0063	0.0065	0.0047	0.017	0.0052− 0.0087
3	0.0054	0.0025	0.0052	0.006	0.0044	0.015	0.0037− 0.0071
3.5	0.004	0.0025	0.0045	0.005	0.0036	0.014	0.0027− 0.0062
4	0.0028	0.0025	0.0039	0.0034	0 0029	0.011	0.0019− 0.0054
5	0.0026	0.0025	0.0038	0.003	0.0022	0.010	0.0018− 0.0052
6	0.002	0.0021	0.0031	0.0025	0.0018	0.008	0.0014− 0.0043
7	0.0017	0.0019	0.0027	0.0025	0.0018	0.0072	0.0012− 0.0037
8	0.0012	0.0018	0.0024	0.002	0.0015	0.0063	0.0008− 0.0033
9	0.0008	0.0017	0.0021	0.002	0.0015	0.0057	0.0005− 0.0029
10	0.0008	0.0015	0.0019	0.0015	0.0011	0.0049	0.0005− 0.0026
12	0.0008	0.0012	0.0016	0.001	0.0007	0.0039	0.0005− 0.0022

TABLE 3.—PROPOSED TOLERANCES FOR CLOSE-FITTING WORM GEARING
Applicable to General Ordnance Construction

Threads per Inch	Maximum Separation of Center Distance from Theoretical	Backlash				Maximum Angular Movement in Degrees of Worm Shaft (Assembled Work)	In Fixtures with Correct Theoretical Center Distances	
		Resulting from Increased Center Distances (20-degree Involute)	Worm	Worm Wheel	Total		Worm and Master Wheel	Wheel and Master Worm
1	0–+0.003	0.00218	+0.001–+0.005	0.004	0.01118	4.02	1.8	1.44
1.5	0.003	0.00218	0.0045	0.0035	0.01018	5.50	2.43	1.89
2	0.003	0.00218	0.004	0.003	0.00918	6.61	2.88	2.16
2.5	0.00275	0.002	0.004	0.00275	0.00875	7.88	3.6	2.48
2.667	0.00275	0.002	0.004	0.00275	0.00875	8.40	3.84	2.64
3	0.00275	0.002	0.00375	0.0025	0.00825	8.91	4.05	2.66
3.5	0.0025	0.00182	0.00375	0.0025	0.00807	10.17	4.72	3.15
4	0.0025	0.00182	0.0035	0.0025	0.00782	11.26	5.18	3.60
5	0.0025	0.00182	+0.0005–+0.00325	0.002	0.00707	12.73	6.35	3.60
6	0.0025	0.00182	0.003	0.00175	0.00657	14.19	6.48	3.78
7	0.002	0.00146	0.0025	0.00175	0.00571	14.39	6.30	4.41
8	0.002	0.00146	0.00225	0.0015	0.00521	15	6.12	4.32
9	0.0015	0.00109	0.00225	0.0015	0.00484	15.68	7.29	4.86
10	0.001	0.00073	0.00225	0.0015	0.00448	16.13	8.1	5.4

Speeds and Feeds for Gear Cutting
(Brown & Sharpe Mfg. Co.)

	Feet
Carbon steel cutters on cast iron.....	60–70 per minute
Carbon steel cutters on steel.....	30–40 per minute
High-speed steel cutters—cast iron...	80–125 per minute
High-speed steel cutters—steel.....	65–100 per minute

The most economical feed is usually *less* than the fastest that the cutter will stand, as there will be less time lost in grinding. As most cutters used in production are of high-speed steel, the following table will be useful:

Diam. Pitch		2	2½	3	4	5	6	7	8	10	12	16
Feed in inches per minute.	Cast iron..	3½	3½	4	4½	4½	5	6	6	7	8	9
	Steel.....	1½	1½	2	2½	2½	3	4	4½	4½	5	6

Grinding Gear Teeth.—Gear teeth have been ground for many years, but the practice was not common until automobile builders adopted it for transmission gears. There are two types of machines, one using a wheel shaped to the space between the gear teeth and the other using the side of a thin disk wheel and rolling it past the curved surface of the tooth. Some machines use steel tapes for generating the curve, while others use a steel former to guide the wheel. These correct distortion due to hardening and can produce a true tooth form. None but the formed wheel grinds more than one tooth face at once.

Composition Gears.—Many gears are now made of fabric, impregnated with compositions of the bakelite order, and called by various trade names, such as Celeron, Formica, etc. They reduce noise when meshed with metal gears, and are sufficiently elastic to cushion shocks that might break metal gears. They are oil- and waterproof and have practically replaced the rawhide gear.

The composition can be machined much like metal. In sawing, a band saw with 5½ teeth per inch, and 0.04 inch thick is advised. Drills will cut a trifle small and are frequently ground off-center to prevent overheating. Reamers will leave holes from 0.001 to 0.002 inch below size.

Cutting off or trepanning tools should have plenty of side clearance. An 8-degree clearance behind the cutting edge and 5- to 10-degree top rake are recommended.

The following pitches are advised for composition gears:

Horse power	D.P.	Horse power	D.P.
Up to ½	10	10–15	3
½–1	8	15–25	2½
1–3	5	25–50	2
3–10	4	50–75	1¾
		75–100	1½

THREADS OF WORMS

Worms are cut with threads having a total angle of 29 degrees, similar to the Acme thread. Some use the same proportions as for the Acme, but most use a deeper thread such as the Brown & Sharpe, which is .6866 deep instead of .51 for a one-inch pitch as in the Acme. It is not easy to cut odd fractional pitches in most lathes, so regular pitches are cut and the circular pitch of the worm wheel is allowed to come in fractional measurements for pitch diameters and center distances. Having determined on the reduction as 40 to 1, the relative proportions can be considered as follows:

Assume a thread of 4 to the inch for the worm or a lead of $\frac{1}{4}$ inch. Then as the reduction of 40 to 1 there must be 40 teeth in the worm gear, $\frac{1}{4}$ inch from center to center of teeth or 10 inches in circumference on the pitch line or 3.18 inches. If a reduction of 20 to 1 is wanted, use the same diam. gear but cut a double thread of 2 per inch, which will give the same distance between teeth, but the worm gear will be moved two teeth every revolution of the worm.

Some of the commonly used proportions are:

$$\text{Pitch diam. of worm gear} = \frac{\text{No. of teeth} \times \text{pitch in inches}}{3.1416}.$$

$$\text{Diametral pitch} = \frac{3.1416}{\text{Linear pitch}}.$$

$$\text{Throat diam. of worm gear} = \text{Pitch diam.} + \frac{2}{\text{Diam. Pitch}}.$$

Outside diameter of gear for 60° sides = throat diameter + 2 (.13397 throat radius.)

Whole depth of tooth of worm or worm gear = .6866 × linear pitch.

Width at top of tooth of worm = .335 × linear pitch.
Width of bottom of tooth of worm = .31 × linear pitch.
Outside diam. of worm — single thread = 4 × linear pitch.
Outside diam. of worm — double thread = 5 × linear pitch.
Outside diam. of worm — triple thread = 6 × linear pitch.
Face of worm gear = $\frac{1}{2}$ to $\frac{3}{4}$ outside diameter of worm.

Width of Face

A common practice for determining the width of face or thickness of worm wheels is shown in Fig. 13. Draw the diameter of the worm and lay off 60 degrees as shown; this gives the width of working face, the sides being made straight from the bottom of the teeth. Others make the face equal to $\frac{3}{4}$ the outside diameter of worm, but $\frac{1}{2}$ the diameter of the worm is more common.

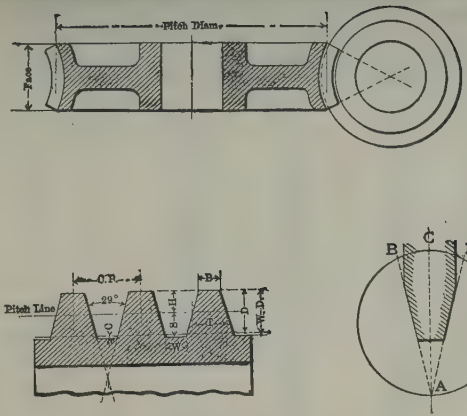


FIG. 13

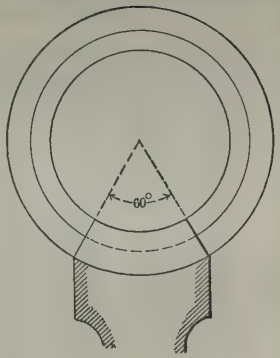


FIG. 14

TO FIND THE PITCH DIAMETER. (Given pitch and number of teeth.)

Rule.—Multiply the number of teeth by the circular pitch and divide by 3.1416.

Example.—Number of teeth 96; Circular pitch, $\frac{1}{4}$. Then $96 \times \frac{1}{4} = 24$. $24 \div 3.1416 = 7.639$ = pitch diameter.

Note.—Diameter of Hob equals diameter of Worm plus twice the clearance "C."

TABLE OF PROPORTIONS OF WORM THREADS TO RUN IN WORM WHEELS

C. P. Circular Pitch	pi. Threads per Inch	D. P. Diametrical Pitch	H. Tooth above Pitch-Line	D. Working Depth of Tooth	C. Clearance	S. Depth of Space below Pitch Line	W. D. Whole Depth of Tooth	T. Thickn. of Tooth on Pitch Line	W. Width of Thread Tool at End	B. Width of Thread at Top
C. P. Inches	pi. $=\frac{1}{C.P.}$	D.P. $=\frac{\pi}{C.P.}$	H. $=\frac{1}{D.P.}$	D. $=2\times\frac{1}{D.P.}$	C. $=\frac{T}{10}$	S. $=H.+C.$	W. D. $=D.+C.$	T. $=\frac{C.P.}{2}$	W. $=.31\times C.P.$	B. $=.335\times C.P.$
2	½	1.5708	.6366	1.2732	.1000	.7366	1.3732	1.0000	.6200	.6708
1¾	⅞	1.7952	.5570	1.1141	.0875	.6445	1.2016	.8750	.5425	.5862
1½	¾	2.0944	.4775	.9549	.0750	.5525	1.0299	.7500	.4650	.5025
1¼	⅝	2.5133	.3979	.7958	.0625	.4604	.8583	.6250	.3875	.4187
1	1	3.1416	.3183	.6366	.0500	.3683	.6866	.5000	.3100	.3350
⅞	1⅛	4.1888	.2387	.4775	.0375	.2762	.5150	.3750	.2325	.2512
¾	1½	4.7124	.2122	.4244	.0333	.2455	.4577	.3333	.2066	.2233
⅝	2	6.2832	.1592	.3183	.0250	.1842	.3433	.2500	.1550	.1675
½	2½	7.8540	.1273	.2546	.0200	.1473	.2746	.2000	.1240	.1340
⅜	3	0.4248	.1061	.2122	.0166	.1227	.2288	.1666	.1033	.1117
⅜	3½	10.9956	.0909	.1819	.0143	.1052	.1962	.1429	.0886	.0957
¼	4	12.5664	.0796	.1591	.0125	.0921	.1716	.1250	.0775	.0838
¼	4½	14.1372	.0707	.1415	.0111	.0818	.1526	.1111	.0689	.0744
¼	5	15.7080	.0637	.1273	.0100	.0737	.1373	.1000	.0620	.0670
¼	6	18.8496	.0531	.1061	.0083	.0614	.1144	.0833	.0517	.0558
¼	7	21.9911	.0455	.0910	.0071	.0526	.0981	.0714	.0443	.0479
¼	8	25.1327	.0398	.0796	.0062	.0460	.0858	.0625	.0388	.0419
¼	9	28.2743	.0354	.0707	.0055	.0409	.0763	.0555	.0344	.0372
⅛	10	31.4159	.0318	.0637	.0050	.0368	.0687	.0500	.0310	.0335
⅛	12	37.6992	.0265	.0530	.0042	.0307	.0572	.0416	.0258	.0279
⅛	14	43.9824	.0227	.0454	.0036	.0263	.0490	.0357	.0221	.0239
⅛	16	50.2655	.0199	.0398	.0031	.0230	.0429	.0312	.0194	.0209
⅛	18	56.5488	.0176	.0352	.0025	.0201	.0377	.0255	.0172	.0186

Note.—The above table refers to single threads only. For Multiple threads, divide the sizes given in the table for the same **lead,** by 2 for double, 3 for triple, 4 for quadruple threads, etc.

To find the Pitch Diameter (given pitch and number of teeth).

Rule.—Multiply the number of teeth by the circular pitch and divide by 3.1416.

Example.—Number of teeth, 96; circular pitch, ¼. Then $96\times\frac{1}{4}=24$. $24\div 3.1416=7.639=$

Gashing Angles for Worm Wheels

Lead of Worm in Inches	No. of Threads per Inch in Worm	Pitch Diameter of Worm														
		⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜	2½
1/10	10	2°55′	2°26′	2° 5′	1°49′	1°37′	1°28′	1°20′	1°13′	1° 7′	1° 2′	58′	55′	52′	49′	46′	44′
1/9	9	3°14′	2°42′	2°19′	2° 1′	1°48′	1°37′	1°28′	1°21′	1°15′	1° 9′	1° 5′	1° 1′	57′	54′	51′	49′
1/8	8	3°38′	3° 2′	2°36′	2°17′	2° 2′	1°49′	1°39′	1°31′	1°24′	1°18′	1°13′	1° 8′	1° 4′	1° 1′	58′	54′
1/7	7	4°10′	3°28′	2°58′	2°36′	2°19′	2° 5′	1°54′	1°44′	1°36′	1°29′	1°23′	1°18′	1°14′	1° 9′	1° 6′	1° 3′
1/6	6	4°51′	4° 3′	3°28′	3° 2′	2°42′	2°26′	2°13′	2° 1′	1°52′	1°44′	1°37′	1°31′	1°26′	1°21′	1°17′	1°13′
1/5	5	5°49′	4°51′	4°10′	3°39′	3°14′	2°55′	2°39′	2°26′	2°15′	2° 5′	2°36′	1°57′	1°43′	1°37′	1°32′	1°27′
1/4	4	7°16′	6° 4′	5°12′	4°33′	4° 3′	3°39′	3°19′	3° 2′	2°48′	2°36′	2°26′	2°17′	2° 9′	2° 2′	1°55′	1°49′
2/7	3½	8°17′	6°55′	5°56′	5°12′	4°37′	4°10′	3°47′	3°28′	3°12′	2°58′	2°47′	2°36′	2°27′	2°19′	2°12′	2° 5′
1/3	3	9°38′	8° 3′	6°55′	6° 3′	5°23′	4°51′	4°25′	4° 3′	3°44′	3°28′	3°14′	3° 2′	2°52′	2°42′	2°33′	2°26′
2/5	2½	10°30′	8°46′	7°32′	6°36′	5°52′	5°17′	4°49′	4°25′	4° 4′	3°47′	3°32′	3°19′	3° 7′	2°57′	2°47′	2°39′
3/8	2⅔	10°49′	9° 3′	7°46′	6°48′	6° 4′	5°27′	4°58′	4°33′	4°12′	3°54′	3°39′	3°25′	3°13′	3° 2′	2°53′	2°44′
2/5	2½	11°31′	9°38′	8°17′	7°15′	6°27′	5°49′	5°17′	4°51′	4°29′	4°10′	3°53′	3°39′	3°26′	3°14′	3° 4′	2°55′
1/2	2¼				8° 3′	7°10′	6°27′	5°52′	5°23′	4°59′	4°37′	4°19′	4° 3′	3°46′	3°30′	3°25′	3°14′
5/8	2						7°15′	6°36′	6° 3′	5°36′	5°12′	4°51′	4°33′	4°17′	4° 3′	3°50′	3°39′
3/4	1¾								6°55′	6°23′	5°56′	5°32′	5°12′	4°54′	4°37′	4°23′	4°10′
7/8	1⅞											6°27′	6° 3′	5°42′	5°23′	5° 6′	4°51′
1	1¾													6°25′	6° 3′	5°44′	5°27′
1	1															6° 7′	5°49′
1½	1½																
1½	1⅜																

Gashing Angles for Worm Wheels. *(Continued)*

Lead of Worm in Inches	No. of Threads per Inch in Worm	Pitch Diameter of Worm														
		2⅜	2¼	2⅛	3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6
1/10	10																
1/9	9																
1/8	8	1° 52′	50′	48′	46′	42′	39′	36′	34′	32′							
1/7	7		1° 57′	54′	52′	48′	45′	42′	39′	37′	35′	33′					
1/6	6	1° 9′	1° 6′	1° 3′	1° 1′	56′	52′	48′	46′	43′	40′	38′	36′	35′			
1/5	5	1° 23′	1° 20′	1° 16′	1° 13′	1° 7′	1° 3′	58′	55′	52′	49′	46′	44′	42′	40′	38′	
1/4	4	1° 44′	1° 39′	1° 35′	1° 31′	1° 24′	1° 18′	1° 13′	1° 8′	1° 4′	1° 1′	58′	55′	52′	50′	48′	46′
2/7	3½	1° 59′	1° 54′	1° 49′	1° 44′	1° 36′	1° 29′	1° 23′	1° 18′	1° 14′	1° 9′	1° 6′	1° 3′	1° 1′	57′	54′	52′
1/3	3	2° 19′	2° 13′	2° 7′	2° 2′	1° 52′	1° 44′	1° 37′	1° 31′	1° 26′	1° 21′	1° 17′	1° 13′	1° 9′	1° 6′	1° 3′	1° 1′
3/8	2¾	2° 31′	2° 25′	2° 18′	2° 13′	2° 2′	1° 54′	1° 46′	1° 39′	1° 34′	1° 28′	1° 24′	1° 20′	1° 16′	1° 12′	1° 9′	1° 6′
2/5	2½	2° 36′	2° 29′	2° 23′	2° 17′	2° 6′	1° 57′	1° 49′	1° 43′	1° 37′	1° 31′	1° 26′	1° 22′	1° 18′	1° 15′	1° 11′	1° 8′
7/16	2⅜	2° 47′	2° 39′	2° 32′	2° 26′	2° 14′	2° 5′	1° 57′	1° 49′	1° 43′	1° 37′	1° 32′	1° 28′	1° 23′	1° 20′	1° 16′	1° 13′
1/2	2¼	3° 5′	2° 57′	2° 49′	2° 42′	2° 30′	2° 19′	2° 10′	2° 2′	1° 54′	1° 48′	1° 42′	1° 37′	1° 33′	1° 28′	1° 24′	1° 21′
9/16	2	3° 28′	3° 19′	3° 10′	3° 2′	2° 48′	2° 36′	2° 26′	2° 17′	2° 9′	2° 2′	1° 55′	1° 49′	1° 44′	1° 39′	1° 35′	1° 31′
5/8	1¾	3° 58′	3° 47′	3° 37′	3° 28′	3° 12′	2° 59′	2° 47′	2° 36′	2° 27′	2° 19′	2° 12′	2° 5′	1° 59′	1° 54′	1° 49′	1° 44′
11/16	1½	4° 37′	4° 25′	4° 13′	4° 3′	3° 44′	3° 28′	3° 14′	3° 2′	2° 52′	2° 42′	2° 33′	2° 26′	2° 19′	2° 13′	2° 7′	2° 1′
3/4	1⅓	5° 12′	4° 58′	4° 45′	4° 33′	4° 12′	3° 54′	3° 39′	3° 25′	3° 13′	3° 2′	2° 53′	2° 44′	2° 36′	2° 29′	2° 23′	2° 17′
13/16	1¼	5° 32′	5° 17′	5° 4′	4° 51′	4° 20′	4° 10′	3° 53′	3° 39′	3° 26′	3° 14′	3° 4′	2° 55′	2° 47′	2° 39′	2° 32′	2° 26′
1	1	6° 55′	6° 36′	6° 10′	6° 3′	5° 36′	5° 12′	4° 51′	4° 33′	4° 17′	4° 3′	3° 50′	3° 39′	3° 28′	3° 19′	3° 10′	3° 2′
1 1/16	15/16			8° 24′	8° 3′	7° 26′	6° 54′	6° 27′	6° 4′	5° 42′	5° 23′	5° 6′	4° 51′	4° 37′	4° 25′	4° 13′	4° 2′
1 1/2	1⅔				9° 3′	8° 22′	7° 46′	7° 15′	6° 49′	6° 26′	6° 4′	6° 44′	5° 27′	5° 12′	4° 58′	4° 45′	4° 33′

LINK BELT SILENT CHAIN DATA

Chain drives should be designed within the following limits for best results:

Encased drives with constant lubrication can be used up to 2,500 feet per minute, but 1,000 to 1,300 feet per minute is most satisfactory.

Minimum center distance = diameter of large wheel + $\frac{1}{2}$ diameter of small wheel. Use *odd* number of teeth in pinions, *even* number of links in chain. For very quiet drives use pinions of 23 teeth or over, a slower chain speed and run in oil. It is always economical to use a chain heavier than the minimum required for the work. Speed ratios as high as 25:1 can be used. Pitches run from $\frac{3}{8}$ to $2\frac{1}{2}$ inches.

To Determine Length of Chain

Subtract diameter of smaller wheel from diameter of larger wheel, and divide the difference by twice the center distance. Find in column *A* the value next larger than this result. Use corresponding values (in same line) from columns *B*, *C* and *D*, and substitute in the following formula:

Length of chain equals the sum of:

Center distance multiplied by value *B*.

Pitch multiplied by number of teeth in smaller wheel and by value *C*.

Pitch multiplied by number of teeth in larger wheel and by value *D*.

Example

14.38-inch pitch diameter, 60 *T*, for $\frac{3}{4}$-inch pitch chain wheel
4.10-inch pitch diameter, 17 *T*, for $\frac{3}{4}$-inch pitch chain pinion
1 foot, $11\frac{1}{4}$ inches = 23.25 inches = center distance
Diam. larger wheel = 14.38 inches
Diam. smaller wheel = 4.10 inches

Difference 10.28 inches

$\frac{10.28}{2 \times 23.25}$ = 0.221 Next larger value in column *A* is 0.22495

Value B, 1.9487 × 23.25 inches center distance = 45.30
Value *C*, 0.4278 × 17 teeth × $\frac{3}{4}$-inch pitch = 5.45
Value *D*, 0.5722 × 60 teeth × $\frac{3}{4}$-inch pitch = 25.75

Length of chain..... = 76.50 inches

Factors for Determining Length of Link-Belt Chain

A	B	C	D	A	B	C	D	A	B	C	D
0.00000	2.0000	0.5000	0.5000	0.26303	1.9296	0.4153	0.5847	0.50754	1.7233	0.3305	0.669
0.00436	2.0000	0.4986	0.5014	0.26724	1.9273	0.4139	0.5861	0.51129	1.7188	0.3292	0.670
0.00873	1.9999	0.4972	0.5028	0.27144	1.9249	0.4125	0.5875	0.51504	1.7143	0.3278	0.672
0.01309	1.9998	0.4958	0.5042	0.27564	1.9225	0.4111	0.5889	0.51877	1.7098	0.3264	0.673
0.01745	1.9997	0.4944	0.5056	0.27983	1.9201	0.4097	0.5903	0.52250	1.7053	0.3250	0.675
0.02181	1.9995	0.4931	0.5069	0.28402	1.9176	0.4083	0.5917	0.52621	1.7007	0.3236	0.676
0.02618	1.9993	0.4917	0.5083	0.28820	1.9151	0.4070	0.5930	0.52992	1.6961	0.3222	0.677
0.03054	1.9991	0.4903	0.5097	0.29237	1.9126	0.4056	0.5944	0.53361	1.6915	0.3208	0.679
0.03490	1.9988	0.4889	0.5111	0.29654	1.9100	0.4042	0.5958	0.53730	1.6868	0.3194	0.680
0.03926	1.9985	0.4875	0.5125	0.30071	1.9074	0.4028	0.5972	0.54097	1.6821	0.3180	0.682
0.04362	1.9981	0.4861	0.5139	0.30486	1.9048	0.4013	0.5986	0.54464	1.6773	0.3166	0.683
0.04798	1.9977	0.4847	0.5153	0.30902	1.9021	0.4000	0.6000	0.54829	1.6726	0.3153	0.684
0.05234	1.9972	0.4833	0.5167	0.31316	1.8994	0.3986	0.6014	0.55194	1.6678	0.3139	0.686
0.05669	1.9968	0.4819	0.5181	0.31730	1.8966	0.3972	0.6028	0.55557	1.6629	0.3125	0.687
0.06105	1.9963	0.4806	0.5194	0.32144	1.8939	0.3958	0.6042	0.55919	1.6581	0.3111	0.688
0.06540	1.9957	0.4792	0.5208	0.32557	1.8910	0.3944	0.6056	0.56280	1.6532	0.3097	0.690
0.06976	1.9951	0.4778	0.5222	0.32969	1.8882	0.3931	0.6069	0.56641	1.6483	0.3083	0.691
0.07411	1.9945	0.4763	0.5237	0.33381	1.8853	0.3917	0.6083	0.57000	1.6433	0.3069	0.693
0.07846	1.9938	0.4750	0.5250	0.33792	1.8824	0.3903	0.6097	0.57358	1.6383	0.3055	0.694
0.08281	1.9931	0.4736	0.5264	0.34202	1.8794	0.3889	0.6111	0.57715	1.6333	0.3042	0.695
0.08716	1.9924	0.4722	0.5278	0.34612	1.8764	0.3875	0.6125	0.58070	1.6282	0.3028	0.697
0.09150	1.9916	0.4708	0.5292	0.35021	1.8733	0.3861	0.6139	0.58425	1.6231	0.3014	0.698
0.09585	1.9908	0.4694	0.5306	0.35429	1.8703	0.3847	0.6153	0.58779	1.6180	0.3000	0.700
0.10019	1.9899	0.4681	0.5319	0.35837	1.8672	0.3833	0.6167	0.59131	1.6129	0.2986	0.701
0.10453	1.9890	0.4667	0.5333	0.36244	1.8640	0.3819	0.6181	0.59482	1.6077	0.2972	0.702
0.10887	1.9881	0.4653	0.5347	0.36650	1.8608	0.3806	0.6194	0.59832	1.6025	0.2958	0.704
0.11320	1.9871	0.4639	0.5361	0.37056	1.8576	0.3792	0.6208	0.60182	1.5973	0.2945	0.705
0.11754	1.9861	0.4625	0.5375	0.37461	1.8544	0.3778	0.6222	0.60529	1.5920	0.2932	0.706
0.12187	1.9851	0.4611	0.5389	0.37865	1.8511	0.3764	0.6236	0.60876	1.5867	0.2917	0.708
0.12620	1.9840	0.4597	0.5403	0.38268	1.8478	0.3750	0.6250	0.61222	1.5814	0.2903	0.709
0.13053	1.9829	0.4583	0.5417	0.38671	1.8444	0.3736	0.6264	0.61566	1.5760	0.2889	0.711
0.13485	1.9817	0.4569	0.5431	0.39073	1.8410	0.3722	0.6278	0.61909	1.5706	0.2875	0.712
0.13917	1.9805	0.4555	0.5445	0.39474	1.8376	0.3708	0.6292	0.62251	1.5652	0.2861	0.713
0.14349	1.9793	0.4542	0.5458	0.39875	1.8341	0.3694	0.6306	0.62592	1.5598	0.2847	0.715
0.14781	1.9780	0.4528	0.5472	0.40275	1.8306	0.3681	0.6319	0.62932	1.5543	0.2833	0.716
0.15212	1.9767	0.4514	0.5486	0.40674	1.8271	0.3667	0.6333	0.63271	1.5488	0.2819	0.718
0.15643	1.9754	0.4500	0.5500	0.41072	1.8235	0.3653	0.6347	0.63608	1.5432	0.2805	0.719
0.16074	1.9740	0.4486	0.5514	0.41469	1.8199	0.3639	0.6361	0.63944	1.5377	0.2792	0.720
0.16505	1.9726	0.4472	0.5528	0.41866	1.8163	0.3625	0.6375	0.64279	1.5321	0.2778	0.722
0.16935	1.9711	0.4458	0.5542	0.42262	1.8126	0.3611	0.6389	0.64612	1.5265	0.2764	0.723
0.17365	1.9696	0.4444	0.5556	0.42657	1.8089	0.3597	0.6403	0.64945	1.5208	0.2750	0.725
0.17794	1.9681	0.4430	0.5570	0.43051	1.8052	0.3583	0.6417	0.65276	1.5151	0.2736	0.726
0.18224	1.9665	0.4416	0.5583	0.43445	1.8014	0.3569	0.6431	0.65606	1.5094	0.2722	0.727
0.18652	1.9649	0.4403	0.5597	0.43837	1.7976	0.3556	0.6444	0.65935	1.5037	0.2708	0.729
0.19081	1.9633	0.4389	0.5611	0.44229	1.7937	0.3542	0.6458	0.66262	1.4979	0.2694	0.730
0.19509	1.9616	0.4375	0.5625	0.44620	1.7899	0.3528	0.6472	0.66588	1.4921	0.2680	0.732
0.19937	1.9599	0.4361	0.5639	0.45010	1.7860	0.3514	0.6486	0.66913	1.4863	0.2667	0.733
0.20364	1.9581	0.4347	0.5653	0.45399	1.7820	0.3500	0.6500	0.67237	1.4804	0.2653	0.734
0.20791	1.9563	0.4333	0.5667	0.45787	1.7780	0.3486	0.6514	0.67559	1.4746	0.2639	0.736
0.21218	1.9545	0.4319	0.5681	0.46175	1.7740	0.3472	0.6528	0.67880	1.4686	0.2625	0.737
0.21644	1.9526	0.4306	0.5694	0.46561	1.7700	0.3458	0.6542	0.68200	1.4627	0.2611	0.738
0.22070	1.9507	0.4292	0.5708	0.46947	1.7659	0.3445	0.6555	0.68518	1.4567	0.2603	0.739
0.22495	1.9487	0.4278	0.5722	0.47332	1.7618	0.3431	0.6569	0.68835	1.4507	0.2584	0.741
0.22920	1.9468	0.4264	0.5736	0.47716	1.7576	0.3417	0.6583	0.69151	1.4447	0.2569	0.743
0.23345	1.9447	0.4250	0.5750	0.48099	1.7535	0.3403	0.6597	0.69466	1.4387	0.2556	0.744
0.23769	1.9427	0.4236	0.5764	0.48481	1.7492	0.3389	0.6611	0.69779	1.4326	0.2542	0.745
0.24192	1.9406	0.4222	0.5778	0.48862	1.7450	0.3375	0.6625	0.70091	1.4265	0.2528	0.747
0.24615	1.9385	0.4208	0.5792	0.49242	1.7407	0.3361	0.6639	0.70401	1.4204	0.2514	0.748
0.25039	1.9363	0.4194	0.5806	0.49622	1.7364	0.3347	0.6653	0.70711	1.4142	0.2500	0.750
0.25460	1.9341	0.4181	0.5819	0.50000	1.7321	0.3333	0.6667				
0.25882	1.9319	0.4167	0.5833	0.50377	1.7277	0.3320	0.6680				

MORSE CHAIN AND SPROCKET DATA

1. Number of Teeth = T.
   Exact Outside Dia. = D.
   When T has less than 33 teeth, D = Pitch Dia.
   When T has more than 32 teeth, D = Pitch Dia. + 2 × Addendum.
2. Use sprockets having an odd number of teeth whenever possible.
3. When specially authorized, a larger number of teeth than shown may be cut in large sprocket.
4. Thickness of sprocket rim, including teeth, should be at least 1.2 times the chain pitch.
5. The number of grooves in the sprocket, their width and distance apart, varies according to pitch and width of chain. In every case leave the designing and turning of these grooves to the Morse Chain Company.
6. The width of the sprocket should be $\frac{1}{8}$ to $\frac{1}{4}$ inch greater than nominal width of the chain.
7. An even number of links in the chain and an odd number of teeth in the wheels are desirable.
8. Horizontal drives preferred with slack on top strand, but for short drives without center adjustment slack should be on the bottom strand.
9. Adjustable wheel centers desirable for horizontal drives and necessary for vertical drives.
10. Avoid vertical drives.

Clearances

11. Allow a side clearance for chain (parallel to axis of sprockets and measured from nominal width of chain) equal to the pitch.
12. Allow a radial clearance over sprocket radius equal to the pitch.
13. Maximum linear velocity for commercial service, 1200 to 1600 feet per minute.

These data are for use in preliminary design; the engineering features should always be submitted to the Morse Chain Company for approval before ordering.

Morse Chain and Sprocket Data

Pitch	3/8	1/2	5/8	3/4	9/10	1 3/10	1 1/2	2	3
Minimum number of teeth: Small sprocket driver	13	13	13	13	15	15	17	17	17
Minimum number of teeth: Small sprocket driven	13	17	17	21	25	29	29	31	35
Desirable number of teeth in driver sprockets	15–17	15–17	17–21	17–21	17–23	17–23	17–27	17–31	19–31
Maximum number of teeth in sprockets (see note 3)	75	99	109	115	125	129	129	129	131
Desirable number of teeth in driven sprockets	35–45	55–75	55–75	55–85	55–95	55–105	55–115	55–115	55–115
To find pitch diameter of wheel multiply number of teeth by (inches)	.1193	.159	.199	.239	.2865	.382	.477	.636	.955
Addendum—for outside diameter of sprockets 33 to 130T (see note 1) (inches)	None	.05	.06	.075	.09	.12	.15	.20	.30
Maximum R.P.M.	6000	2400	1800	1200	1100	800	600	400	250
Tension per inch width chain, pounds: Small sprocket driver	60	80	100	120	150	200	270	450	750
Tension per inch width chain, pounds: Small sprocket driven	60	65	80	95	120	160	210	350	600
Radial clearance beyond tooth required for chain (inches)	.375	.50	.62	.75	.90	1.2	1.5	2.	3.
Approximate weight of chain per inch width, 1 foot long (pounds)	.75	1.00	1.20	1.50	1.80	2.50	3.	4.	6.
C Constants for solid pinions	.003	.0045	.0063	.009	.013	.023	.035	.058	.145
C Constants for armed sprockets	.10	.16	.25	.35	.45	.7	1.	2.	4.

Approximate Weight for Solid Pinions and Armed Sprockets

When T = Number of teeth. F = Face in inches. C = Constant in pounds per inch in face per tooth. $T^2 \times F \times C$ = weight of armed sprocket. Add 25 per cent. if split; add 50 per cent. if spring sprocket and split. For solid pinions: $C \times T^2 \times (F + 1) =$

ROLLER TRANSMISSION CHAIN

Revised Recommended Practice for Roller Transmission Chains and Sprockets, by American Gear Manufacturers' Association, May, 1925.

Section Profile

Showing Recommended Chamfering of Sprocket Teeth for Chains

P = pitch of chain. C = Depth of chamfer $0.3\,P$.
W = chain width. E = Width of chamfer $\frac{1}{8}\,P$.
$T = 0.93\,W - 0.006''$. R = Tooth radius $0.43\,P$ or over.

Limits on sprocket thickness, $\pm\left(\frac{W}{100} + 0.002''\right)$

Table 4
(All Dimensions in Inches)

Width of Chain, W	Sprocket Thickness T	Limits on Thickness	Nominal Clearance (W-T)
$\frac{5}{32}$	0.139	±0.003	0.017
$\frac{7}{32}$	0.198	±0.004	0.021
$\frac{1}{4}$	0.227	±0.004	0.023
$\frac{5}{16}$	0.284	±0.005	0.028
$\frac{3}{8}$	0.343	±0.006	0.032
$\frac{1}{2}$	0.459	±0.007	0.041
$\frac{5}{8}$	0.575	±0.008	0.050
$\frac{3}{4}$	0.692	±0.010	0.058
$\frac{7}{8}$	0.808	±0.011	0.067
1	0.924	±0.012	0.076
$1\frac{1}{8}$	1.040	±0.013	0.085
$1\frac{1}{4}$	1.156	±0.015	0.094
$1\frac{9}{16}$	1.447	±0.017	0.115

Table 5
(All Dimensions in Inches)

Pitch	Depth of Chamfer C	Width of Chamfer E	*Limits on Bottom Diameter
$\frac{3}{8}$	0.113	$\frac{3}{64}$	+0.000; −0.004
$\frac{1}{2}$	0.150	$\frac{1}{16}$	+0.000; −0.006
$\frac{5}{8}$	0.188	$\frac{5}{64}$	+0.000; −0.007
$\frac{3}{4}$	0.225	$\frac{3}{32}$	+0.000; −0.009
1	0.300	$\frac{1}{8}$	+0.000; −0.012
$1\frac{1}{4}$	0.375	$\frac{5}{32}$	+0.000; −0.015
$1\frac{1}{2}$	0.450	$\frac{1}{16}$	+0.000; −0.018
$1\frac{3}{4}$	0.525	$\frac{7}{32}$	+0.000; −0.021
2	0.600	$\frac{1}{4}$	+0.000; −0.024
$2\frac{1}{2}$	0.750	$\frac{5}{16}$	+0.000; −0.030
3	0.900	$\frac{3}{8}$	+0.000; −0.036
4	1.20	$\frac{1}{2}$	+0.000; −0.048
5	1.50	$\frac{5}{8}$	+0.000; −0.060

*Negative limit = $-0.012\,P$.

Pitch diameter of sprocket $= P \div \sin \frac{180^\circ}{T}$, where P is the pitch, and T is the number of teeth.

Bottom diameter of sprocket = pitch diameter − roller diameter

Outside diameter of sprocket (minimum) $= P\left(0.6 + \cot \frac{180^\circ}{T}\right)$.

TABLE 6.—STANDARD PITCH DIAMETERS AND OUTSIDE DIAMETERS OF SPROCKETS, 1-INCH PITCH ROLLER CHAIN

For other pitches multiply these values by the pitch.

To obtain bottom diameters subtract diameter of chain roller from pitch diameter.

(All Dimensions in Inches)

No. Teeth	Pitch Diameter	Outside Diameter	No. Teeth	Pitch Diameter	Outside Diameter	No. Teeth	Pitch Diameter	Outside Diameter
6	2.0000	2.332	46	14.6536	15.219	86	27.3807	27.962
7	2.3048	2.677	47	14.9717	15.538	87	27.6989	28.281
8	2.6131	3.014	48	15.2898	15.857	88	28.0171	28.599
9	2.9238	3.347	49	15.6079	16.176	89	28.3354	29.918
10	3.2361	3.678	50	15.9260	16.495	90	28.6536	29.236
11	3.5495	4.006	51	16.2441	16.813	91	28.9718	29.554
12	3.8637	4.332	52	16.5619	17.132	92	29.2900	29.873
13	4.1785	4.657	53	16.8803	17.451	93	29.6082	30.191
14	4.4940	4.982	54	17.1984	17.769	94	29.9264	30.510
15	4.8097	5.305	55	17.5166	18.088	95	30.2446	30.828
16	5.1259	5.627	56	17.8347	18.406	96	30.5628	31.146
17	5.4423	5.950	57	18.1529	18.725	97	30.8811	31.465
18	5.7588	6.271	58	18.4710	19.044	98	31.1994	31.783
19	6.0756	6.593	59	18.7892	19.363	99	31.5177	32.102
20	6.3925	6.914	60	19.1073	19.681	100	31.8360	32.420
21	6.7095	7.235	61	19.4255	20.000	101	32.1543	32.739
22	7.0266	7.555	62	19.7437	20.318	102	32.4726	33.057
23	7.3439	7.875	63	20.0618	20.637	103	32.7909	33.376
24	7.6613	8.196	64	20.3800	20.955	104	33.1091	33.694
25	7.9787	8.516	65	20.6982	21.274	105	33.4274	34.012
26	8.2962	8.836	66	21.0164	21.593	106	33.7457	34.331
27	8.6138	9.156	67	21.3346	21.911	107	34.0640	34.649
28	8.9315	9.475	68	21.6528	22.230	108	34.3823	34.968
29	9.2491	9.795	69	21.9710	22.548	109	34.7006	35.286
30	9.5668	10.114	70	22.2892	22.867	110	35.0189	35.605
31	9.8845	10.434	71	22.6074	23.185	111	35.3371	35.923
32	10.2023	10.753	72	22.9256	23.504	112	35.655	36.241
33	10.5201	11.072	73	23.2438	23.822	113	35.974	36.560
34	10.8380	11.392	74	23.5620	24.141	114	36.292	36.878
35	11.1558	11.711	75	23.8802	24.459	115	36.610	37.197
36	11.4737	12.030	76	24.1984	24.778	116	36.929	37.515
37	11.7917	12.349	77	24.5166	25.096	117	37.247	37.833
38	12.1096	12.668	78	24.8349	25.415	118	37.565	38.152
39	12.4275	12.987	79	25.1531	25.733	119	37.883	38.470
40	12.7455	13.306	80	25.4713	26.052	120	38.201	38.788
41	13.0635	13.625	81	25.7895	26.370	121	38.519	39.106
42	13.3815	13.944	82	26.1078	26.689	122	38.837	39.425
43	13.6995	14.263	83	26.4260	27.007	123	39.156	39.743
44	14.0175	14.582	84	26.7443	27.326	124	39.475	40.062
45	14.3356	14.901	85	27.0625	27.644	125	39.794	40.381

Recommended Sizes of Cutters for Block-Chain Sprockets
(All Dimensions in Inches.)

Pitch of Chain	Block End Diam.	Pitch of Block	Cutter Diam.	Bore	Keyway	Cutter Width					
						$6T$	7–$8T$	9–$11T$	12–$17T$	18–$34T$	$35T$ up
1	0.325	0.400	3	1	$\frac{5}{32} \times \frac{6}{64}$	$1\frac{3}{16}$	$1\frac{5}{32}$	$1\frac{5}{32}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{3}{32}$
$1\frac{1}{2}$	0.531	0.563	4	$1\frac{1}{4}$	$\frac{3}{16} \times \frac{3}{32}$	$1\frac{25}{32}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{1}{16}$	$1\frac{1}{16}$	$1\frac{1}{8}$

Recommended Cutter Sizes for Roller-Chain Sprockets
(All Dimensions in Inches)

Pitch	Roll Diam.	Cutter Diameter, Minimum						Cutter Width, Minimum						Bore	Keyway
		$6T$	7–$8T$	9–$11T$	12–$17T$	18–$34T$	$35T$ and over	$6T$	7–$8T$	9–$11T$	12–$17T$	18–$34T$	$35T$ and over		
$\frac{3}{8}$	0.200	$2\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$	$\frac{15}{32}$	$\frac{15}{32}$	$\frac{15}{32}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{13}{32}$	$\frac{1}{4}$	$\frac{5}{32} \times \frac{6}{64}$
$\frac{1}{2}$ to $\frac{5}{8}$	0.313	3	3	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$\frac{23}{32}$	$\frac{23}{32}$	$\frac{23}{32}$	$\frac{11}{32}$	$\frac{11}{32}$	$\frac{11}{16}$	$\frac{1}{4}$	$\frac{5}{32} \times \frac{6}{64}$
$\frac{3}{4}$	0.400	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$\frac{29}{32}$	$\frac{29}{32}$	$\frac{29}{32}$	$\frac{7}{8}$	$\frac{27}{32}$	$\frac{13}{16}$	$\frac{5}{16}$	$\frac{5}{32} \times \frac{6}{64}$
$\frac{3}{4}$	0.469	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$\frac{29}{32}$	$\frac{29}{32}$	$\frac{29}{32}$	$\frac{7}{8}$	$\frac{27}{32}$	$\frac{13}{16}$	$\frac{5}{16}$	$\frac{5}{32} \times \frac{6}{64}$
1	0.563

MILLING AND MILLING CUTTERS

MILLING MACHINE FEEDS AND SPEEDS

The determining of the proper feeds of milling cutters in the past was usually a matter of guesswork, or experience, no absolute rule of any kind having ever been established.

A guide for determining the proper feed of milling cutters is found in ascertaining the thickness of the chip per tooth of the cutter.

Taking, for example, an average size milling cutter working in cast iron, say $2\frac{1}{2}$ inches diameter, 3 inches long, with eighteen teeth, which is quite commonly used, and it will be found that the thickness of the chip per tooth is quite small, resulting in .0018 inch, with a table feed of 2 inches per minute. This is entirely too slow. Now, comparing this cut of .0018 inch with a lathe tool cut, it will be seen that such a chip in a milling cutter is much smaller and is far more injurious to the cutter than a heavier feed, since the cutting edge of a tool will hold up longer in cutting into the metal instead of scraping it.

A cutter is very seldom ruined by the feed, but is generally ruined by overspeeding it. For instance, with a cutter of thirty teeth with a table feed of .300 inch per revolution, the chip per tooth will then only be $\frac{.300}{30T} = .010$ inch thick—still quite a light cut when comparing it with a lathe tool chip. Hence in many cases of milling, if the feeds are guided by the thickness of chip per tooth, a much faster feed would be used, since it is evident that the heaviest feeds, comparatively, give only a thin chip per tooth.

Cutting Speeds

The Brown & Sharpe Mfg. Co. say:

The feeds and speeds of cutters cannot be governed by any definite rules, but, in a general way the following surface speeds will serve to give an idea, or basis to work from. They may be varied slightly to suit the requirements of the work in hand. Using carbon steel cutters: For brass, 80 feet to 100 feet per minute; for cast iron, 40 feet to 60 feet per minute; for machinery steel, 30 feet to 40 feet per minute; and for annealed tool steel, 20 feet to 30 feet per minute have been found satisfactory. With high speed steel cutters for the same materials, the following speeds are advocated: For brass, 150 feet to 200 feet per minute; for cast iron, 80 feet to 100 feet per minute; for machinery steel, 80 feet to 100 feet per minute; and for annealed tool steel, 60 feet to 80 feet per minute.

On steel of 65,000 tensile strength, with a cut 6 inches wide by $\frac{3}{16}$ inch deep, a feed of 16 inches per minute can be maintained for

long periods. At 60 revolutions per minute and a feed of 0.262 per revolution 18 cubic inches per minute was removed with 21 horse-power.

It is not always advisable to maintain the highest cutter speeds as a slower speed and heavier feed will prevent vibration and chatter. These are not maximum results but can be attained under regular working conditions. The horsepower required for removing a cubic inch of metal per minute on the milling machine may be safely considered as $1\frac{1}{4}$ horsepower for steel and $\frac{3}{4}$ horsepower for cast iron.

The Action of a Milling Cutter

The action of the ordinary milling cutter with a radial tooth is not a true cutting action, as it is commonly understood. By a true cutting action is meant the driving of a wedge-shaped tool between

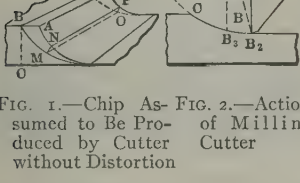


Fig. 1.—Chip Assumed to Be Produced by Cutter without Distortion

Fig. 2.—Action of Milling Cutter

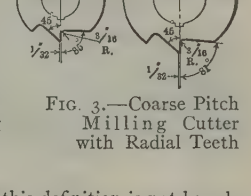


Fig. 3.—Coarse Pitch Milling Cutter with Radial Teeth

the work and the chip and, although this definition is not based on a generally accepted meaning of the term, it is believed that it expresses fairly well what most mechanics understand by cutting. Radial tooth cutters cannot drive a wedge between chip and work. The tooth compresses the metal until it produces a strain great enough to cause a plane of cleavage at some angle with the direction of the cutter. It then begins to compress a new piece, push it off, and so on.

The chip taken by a milling cutter varies very materially from those taken by a lathe or planer tool. These latter tools make chips of uniform section, whereas the section of a milling chip increases from zero to a maximum.

Fig. 1 shows a milling chip as it would appear, if no compression or distortion took place. The proportions are very much exaggerated, so as to bring its typical shape clearer into view. The width $A\ B$ at the top is equal to the feed per tooth. The height $B\ C$ is the depth of cut. The length $B\ D$ is the width of cut. The section $M\ N\ O\ P$, shown halfway on the chip, is a normal section and a measure of the amount of work which was done at the time the cutter passed the point M.

Fig. 2 shows the action of a milling cutter, with center O, when the cutter is rotating and the work is feeding at the same time. The tooth $A\ B$ sweeps through the path $B\ C$. When the point B has

reached the position B_1, a new tooth starts cutting. By this time O has advanced to position O_2, and the new tooth $A_2 B_2$ is not yet in a vertical position, when the point B_2 touches the work. When the cutter revolves, this point B_2 must penetrate into the work and compress the metal of the work. The result will be spring in the arbor. When this spring has assumed certain proportions, the blade or tooth begins to remove a chip. This may be assumed to take place in the position B_3, the tooth simply gliding over the work from B_2 to B_3. This action must necessarily be very harmful to the cutter, and it was believed that this, perhaps more than any other action of the cutter, caused its dulling. It would be especially severe with light cuts, as a relatively small amount of spring would allow the point B_2 to travel through a large arc. It would be quite possible that a tooth should fail entirely to take a chip, and that the succeeding tooth would take a chip of double the amount.

Fig. 3 shows a milling cutter with coarse teeth but with radial teeth instead of having the teeth undercut, or with a rake on the cutting surface.

Form of Tooth in the New Cutter

The foregoing considerations led to a gradual evolution of spiral milling cutters and a rake on the cutting edge. At first, the number of teeth of spiral mills was only slightly diminished, as it was thought that some element which was not considered might affect the result. Gradually the spacing was increased and the cutters, as now used, have taken the forms shown in Figs. 6, 7 and 8, with a rate of about 10 deg. on the cutting surface.

The Finish of the Work

It is a common belief that better finish can be obtained with teeth closely spaced, but experience with the wide-spaced cutter shows that there is no ground for this belief. The grade of finish may be expressed by the distance between successive marks on the work. These marks are revolution marks and not tooth marks. It is practically impossible to avoid these revolution marks. They are caused by the cutter not being exactly round or quite concentric with the hole, by the hole not being of exactly the same size as the arbor, by the arbor not being round, by the straight part of the arbor not being concentric with the taper shank, by the taper shank not being round or of the same taper exactly as the taper hole in the spindle, by this taper hole being out of line with the spindle, by looseness between the spindle and its bearings, etc. Each of these items is very small in any good milling machine; yet the accumulation of these little errors is sufficient to cause a mark, and this mark needs to have a depth of only a fraction of a thousandth of an inch to be very plainly visible. As these marks are caused by conditions which return once for every revolution of the cutter, it is plain that the spacing of the teeth can have no effect on the distance between them and, therefore, on the grade of finish. This has been proven by actual tests.

Coarse Tooth Cutters

Tests by Prof. J. A. Hall and Benj. P. Graves at the Brown & Sharpe Mfg. Co. show that coarse-tooth milling cutters require

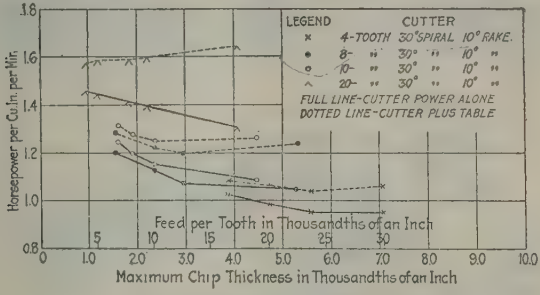


Fig. 4.—Hp. Required by Milling Cutters

less power to remove a given amount of metal per minute than fine-tooth cutters. This is true on both wide and narrow work, although the margin in favor of the coarse-tooth cutter is greater on wide cuts. It is also true if both cutters are compared on a chip-per-tooth basis.

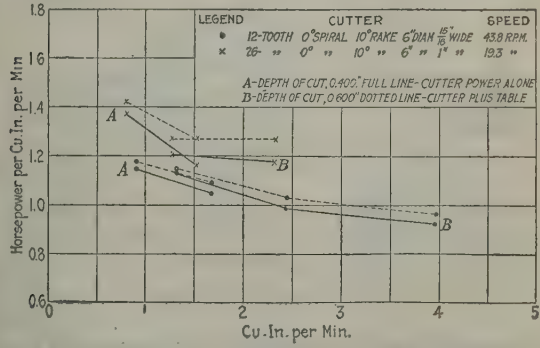


Fig. 5.—Hp. as Affected by Amount Removed

When compared on a chip-per-tooth basis, the finish given by the coarse-tooth cutter is better than that by the fine-tooth cutter on account of the closer spacing of revolution marks.

Low-cutting-speed operation of fine-tooth cutters to give a large feed per tooth is objectionable on account of the increased stresses in the machine and holding fixtures.

Fine-tooth cutters are much inferior to coarse-tooth cutters when the relative tendency to chatter is considered. Milling efficiency is increased by greater feeds per tooth. Few teeth and high speed require the least power. The limits are the shock due to hammer of

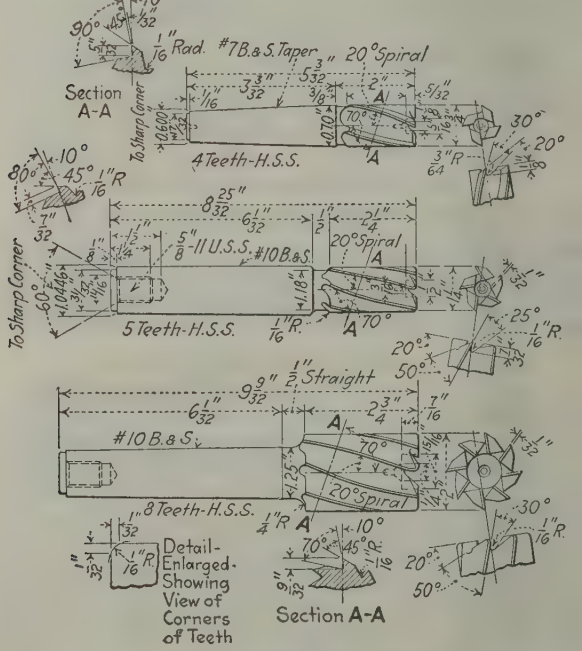


FIG. 6.—Spiral End Mills

cutting edges on work and overheating tooth edges due to heavy pressures and high speeds. There is little danger of breaking teeth in a well designed, modern cutter.

Moderate rake angles reduce the power consumption and are desirable on all cutters to be used on mild steel. Large rake angles are undesirable due to the tendency to chatter. A cutting rake

of 10 degrees takes from 20 to 25 per cent less power than a radial tooth. Beyond 10 degrees the power saved is very little and there is more tendency to chatter. This limitation is more serious than the danger of burning or chipping the edge.

The spiral angle has little effect on the power consumption. A considerable spiral angle is desirable, however, because it makes possible the use of fewer teeth, gives smoother cutter action and reduces the tendency to chatter. Angles of from 10 to 60 degrees

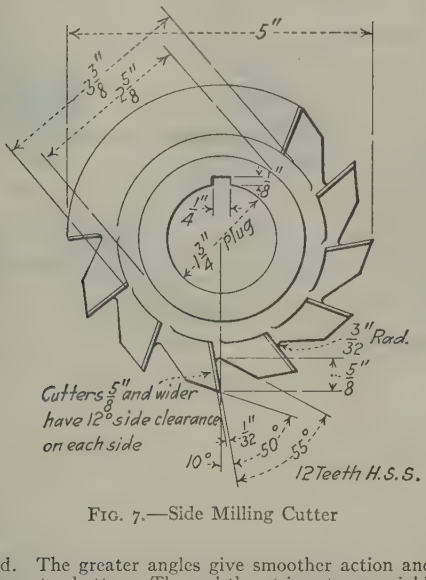


FIG. 7.—Side Milling Cutter

were tried. The greater angles give smoother action and reduce the tendency to chatter. The end thrust is not appreciable, nor is there any reduction in power consumed. If the work extends beyond the cutter there is a possibility of burning the corners of the teeth. Figs. 4 and 5 show power required with modern cutter having rate and clearance show on the charts.

With the few exceptions noted, coarse-tooth cutters of the type now generally manufactured are superior to fine-tooth cutters for all classes of production work.

Fig. 6 shows three standard end mills of the Cincinnati Milling Machine Company. The angle of the spiral (more correctly a helix) is now made 20 degrees. These end mills also have the teeth undercut 10 degrees and the faces of the end teeth are cut

back of the radial line the same amount. The backs of the teeth are formed with double angles to give the required strength.

A modern 5-inch side milling cutter of the same make is shown in Fig. 7. The peripheral teeth are undercut 10 degrees, and on cutter $\frac{5}{8}$ inch and wider the side teeth have 12 degrees side clearance. For milling slots where the width must be maintained, cutters in two parts, in which the teeth overlap or interlock, are used, as in Fig. 10. The halves can be separated by spacers and the staggered teeth prevent any hammer-blow action when widely spaced.

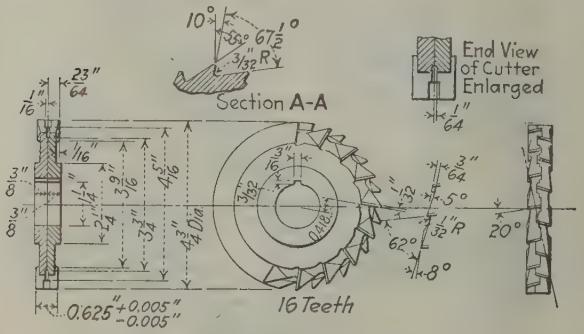
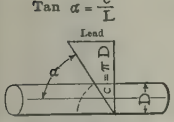


FIG. 8.—Interlocking Cutters

Tables for Use in Cutting Spirals on Universal Milling Machines

The following tables show the leads of cutter spirals used by the Brown & Sharpe Mfg. Co. together with pitches and approximate angles for cutting spirals on universal milling machines. The necessary explanations are given in the note in the tables, these being made clear by the accompanying diagram.



Leads of B. & S. Cutter Spirals (Helices)

The leads of the Brown & Sharpe Cutter Spirals are as follows:

$$\text{Tan } \alpha = \frac{C}{L}$$

Diam. of Cutter	Lead	Diam. of Cutter	Lead
½″	7.29″	2″	31.5″
⅝– ¾″	9.52″	2¼–2½″	36″
⅞″	13.71″	2¾–3″	48″
1 –1¼″	17.14″	3½–3¾″	60″
1½″	23.33″	4″	68.57″
1¾″	28″		

TABLE OF PITCHES AND APPROXIMATE ANGLES FOR CUTTING SPIRALS (HELICES) ON THE UNIVERSAL MILLING MACHINE



To find the angle for cutters of a larger diameter than given in the table, make a drawing as shown in the diagram; the angle *b* being a right angle. Let *b c* equal the circumference. Let *a b* equal the pitch. Connect *c a* by a line, and measure the angle *a* with a protractor; or divide the circumference by the lead and the quotient will be the tangent of the angle. Find the angle in a table of tangents.

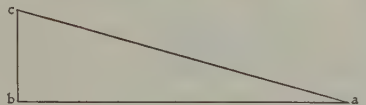
Gear on Worm	First Gear on Stud	Second Gear on Stud	Gear on Screw	Pitch in Inches to one Turn	Diameter of Mill, Cutter, or Drill to be Cut in Inches. Values Given Under Diameters are Angles in Degrees																		
					$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4
24	64	24	72	1.25	$17\frac{1}{2}$	$32\frac{1}{4}$																	
24	64	28	72	1.46	$14\frac{1}{4}$	28	$38\frac{1}{2}$																
24	64	30	72	1.56	$14\frac{1}{4}$	$26\frac{3}{4}$	37																
24	64	32	72	1.67	$12\frac{3}{4}$	25	$34\frac{3}{4}$	$43\frac{1}{4}$															

$$\text{The lead in inches in one turn} = \frac{10 \times \text{Gear on Worm} \times \text{2nd Gear on Stud}}{\text{Gear on Screw} \times \text{1st Gear on Stud}}$$

32	64	28	72	1.94	11¼	21¾	31	39	45														
24	64	40	72	2.08	10¼	20½	29½	37	43¼														
32	56	28	72	2.22	9¾	19¼	27½	35	41¼														
24	64	48	72	2.50	8¾	17	25	32	38	43¼													
40	56	28	72	2.78	8	15½	23	29½	35¼	40½	44¾												
24	64	56	72	2.92	7½	15	21¾	28¼	34	39	43¼												
40	48	28	72	3.24	6¾	13¼	19¾	25¾	31¼	36	40½	44¼											
40	48	32	72	3.70	6	11¾	17½	23	28	32½	36½	40½											
56	48	24	72	3.89	5½	11¼	16¾	22	26¾	31¼	35¼	39											
40	72	48	64	4.17	5¼	10½	15¾	20½	25¼	29½	33½	37	43¼										
56	48	28	72	4.53	5	9¾	14¾	19¼	23¾	27¾	31½	35	41½										
40	64	56	72	4.86	4½	9	13½	17¾	22	25¾	29½	33	39	44¼									
48	40	32	72	5.33	4	8¼	12¼	16¼	20¼	23¾	27¼	30½	36½	41½									
56	40	28	72	5.44	4	8	12	16	20	23½	26¾	30	36	41									
56	40	28	64	6.12	3½	7¼	11	14½	17¾	21	24¼	27	33	37¾	42								
56	40	32	72	6.22	3½	7	10¾	14¼	17½	20¾	23¾	26¾	32½	37¼	41½								
56	48	40	72	6.48	3¼	6¾	10¼	13½	16¾	20	23	25¾	31½	36¼	40¼	44¼							
64	48	28	56	6.67	3¼	6½	10	13¼	16½	19½	22½	25¼	30¼	35¼	39½	43½							
56	48	40	64	7.29	3	6¼	9¼	12¼	15	18	20½	23½	28¼	33	37	41	44¼						
64	48	40	72	7.41	3	6	9	12	14¾	17¾	20¼	22¾	28¼	32½	36½	40¼	43¾						
64	48	32	56	7.62	2¾	5¾	8¾	11½	14½	17¼	19¾	22¼	27½	32	36	39½	43						
48	32	40	72	8.33	2½	5¼	8	10½	13¼	15¾	18¼	20½	25½	29½	33½	37	40½	43½					
72	30	24	64	9.00	2½	5	7½	10	12½	14¾	17	19¼	24	28	31¾	35¼	38½	41¼	44				
56	40	48	72	9.33	2¼	4¾	7¼	9½	11¾	14	16¼	18½	23	27	30½	34	37¼	40¼	43				
64	48	40	56	9.52	2¼	4½	7	9¼	11½	13¾	16	18¼	22½	26½	30	33½	36½	39½	42¼	45			
72	40	32	56	10.29	2	4¼	6½	8¾	10¾	12¾	15	17¼	21	24¾	28¼	31½	34½	37½	40	42½	45		
64	48	56	72	10.37	2	4¼	6½	8½	10½	12¾	14¾	17	20¾	24½	28	31¼	34¼	37¼	39¾	42¼	44¾		
48	40	56	64	10.50	2	4¼	6¼	8½	10½	12½	14½	16¾	20½	24¼	27¾	31	34	36¾	39½	42	44¼		

TABLE OF PITCHES AND APPROXIMATE ANGLES FOR CUTTING SPIRALS (HELICES) ON THE UNIVERSAL MILLING MACHINE

(Continued)



To find the angle for cutters of a larger diameter than given in the table, make a drawing as shown in the diagram; the angle *b* being a right angle. Let *b c* equal the circumference. Let *a b* equal the pitch. Connect *c a* by a line, and measure the angle *a* with a protractor; or divide the circumference by the lead and the quotient will be the tangent of the angle. Find the angle in a table of tangents.

Gear on Worm	First Gear on Stud	Second Gear on Stud	Gear on Screw	Pitch in Inches to one Turn	Diameter of Mill, Cutter, or Drill to be Cut, Inches. Values Given Under Diameters are Angles in Degrees																			
					$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4
64	40	48	72	10.67	2	4	$6\frac{1}{4}$	$8\frac{1}{2}$	$10\frac{1}{4}$	$12\frac{1}{4}$	$14\frac{1}{4}$	$16\frac{1}{2}$	$20\frac{1}{4}$	24	$27\frac{1}{4}$	$30\frac{1}{2}$	$33\frac{1}{2}$	$36\frac{3}{4}$	39	$41\frac{1}{2}$	$43\frac{3}{4}$			
56	32	40	64	10.94	2	4	6	$8\frac{1}{4}$	$10\frac{1}{4}$	12	14	$16\frac{1}{4}$	20	$23\frac{1}{2}$	$26\frac{3}{4}$	30	33	$35\frac{3}{4}$	$38\frac{1}{4}$	$40\frac{3}{4}$	43			
64	32	40	72	11.11	2	4	6	8	10	$11\frac{3}{4}$	$13\frac{3}{4}$	16	$19\frac{3}{4}$	23	$26\frac{1}{2}$	$29\frac{1}{2}$	$32\frac{1}{2}$	$35\frac{1}{4}$	38	$40\frac{1}{4}$	$42\frac{1}{2}$			
56	32	48	72	11.66	$1\frac{3}{4}$	$3\frac{3}{4}$	$5\frac{3}{4}$	$7\frac{1}{2}$	$9\frac{1}{2}$	$11\frac{1}{4}$	$13\frac{1}{4}$	$15\frac{1}{4}$	$18\frac{3}{4}$	22	$25\frac{1}{4}$	$28\frac{1}{2}$	$31\frac{1}{4}$	34	$36\frac{1}{2}$	39	$41\frac{1}{4}$	$43\frac{1}{2}$		

72	40	32	48	12.00	1¾	3¾	5½	7¼	9¼	11	12¾	15	18¼	21½	24¾	27¾	30½	33¼	35¾	38	40¼	42½	44¾	
56	32	48	64	13.12	1½	3½	5¼	6¾	8½	10¼	11¾	13½	16¾	20	22¾	25¾	28¼	31	33¼	35¾	37¾	40	42	43¾
56	28	48	72	13.33	1½	3¼	5	6½	8¼	10	11½	13¼	16½	19½	22½	25½	28	30½	33	35¼	37½	39½	41½	43¼
64	40	48	56	13.71	1½	3¼	4¾	6½	8	9¾	11¼	13	16	19	22	24¾	27¼	30	32¼	34½	36½	38¾	40¾	42½
64	28	48	72	15.24	1¼	3	4½	5¾	7¼	8¾	10¼	11¾	14½	17¼	20	22½	25	27¼	29½	31¾	34	35¾	37¾	39½
64	32	56	72	15.56	1¼	2¾	4¼	5¾	7¼	8¾	10	11½	14¼	17	19½	22	24½	27	29	31¼	33¼	35¼	37	39
56	64	72	40	15.75	1¼	2¾	4¼	5½	7	8½	9¾	11¼	14	16¾	19¼	21¾	24¼	26½	28¾	31	33	35	36¾	38½
72	32	48	64	16.87	1¼	2½	4	5¼	6¾	8	9¼	10½	13¼	15¾	18¼	20½	22¾	25	27	29¼	31¼	33½	35	36½
64	32	48	56	17.14	1¼	2½	4	5¼	6¾	7¾	9	10¼	13	15½	17¾	20¼	22¼	24¾	26¾	29	30¾	32¾	34½	36
72	32	40	48	18.75	1	2¼	3½	4¾	6	7¼	8¼	9½	12	14¼	16½	18½	20¾	22¾	25	26¾	28½	30¼	32	33¾
72	32	48	56	19.29	1	2¼	3½	4½	5¾	6¾	8	9¼	11½	13¾	16	18¼	20¼	22¼	24	26	28	29¾	31½	33
64	28	48	56	19.59	1	2¼	3¼	4½	5¾	6¾	8	9¼	11½	13½	15¾	18	20	22	23¾	25¾	27½	29¼	31	32¾
72	32	56	64	19.69	1	2¼	3¼	4¼	5¾	6¾	8	9	11½	13½	15¾	17¾	20	21¾	23¾	25½	27½	29¼	31	32½
72	24	40	56	21.43	1	2	3¼	4¼	5¼	6¼	7½	8½	10½	12½	14½	16½	18½	20¼	22	23¾	25½	27¼	29	30¼
72	28	56	64	22.50	1	2	3	4	5	6	7	8	10	12	13¾	15¾	17½	19¼	21	22¾	24½	26	27¾	29¼
64	32	56	48	23.33	1	2	3	4	5	5¾	6¾	7¾	9¾	11½	13¼	15¼	17	18¾	20½	22	23½	25¼	27	28¼
72	24	56	64	26.25	1	1¾	2¾	3½	4¼	5	6	7	8½	10¼	12	13½	15	16¾	18¼	19¾	21¼	22¾	24¼	25½
64	28	56	48	26.67	1	1¾	2¾	3½	4¼	5	6	6¾	8½	10	11¾	13¼	14¾	16½	18	19½	21	22¼	23¾	25¼
64	32	56	40	28.00	1	1¾	2½	3¼	4	4¾	5¾	6½	8	9¾	11¼	12¾	14¼	15¾	17¼	18¾	20	21½	22¾	24
72	28	48	40	30.86	1	1½	2¼	3	3	3¾	4½	5	5¾	7¼	8¾	10	11½	13	14¼	15½	17	18½	19¾	21	22
72	32	56	40	31.50	1	1½	2¼	3	3	3¾	4¼	5	5¾	7¼	8½	10	11¼	12¾	14	15½	16½	18	19¼	20½	21¾
72	32	64	40	36.00	1	1¼	2	2½	3¼	3¾	4¼	5	6¼	7½	8¾	10	11	12¼	13½	14¾	16	17	18¼	19¼	
72	28	64	40	41.14	1	1¼	1¾	2¼	2¾	3¼	4	4½	5½	6½	7¾	8¾	9¾	10¾	11¾	13	14	15	16	17	
72	28	56	32	45.00	1	1	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	12¼	13¼	14¾	15½		
72	24	64	40	48.00	1	1	1½	2	2½	3	3¼	3¾	4¾	5½	6½	7½	8½	9¼	10¼	11¼	12	13	13¾	14½		
72	28	64	32	51.43	¾	¾	1¼	1½	2¼	2¾	3	3¾	4½	5¼	6	7	7¾	8¾	9½	10½	11¼	12	12¾	13¾	
72	24	64	32	60.00	¾	¾	1¼	1½	2	2¼	2½	3	3¾	4	4¾	5¼	6	6¾	7½	8¼	9	9½	10¼	11	11¾
72	24	64	28	68.57	¾	¾	1¼	1¾	2	2¼	2½	3½	3¾	4	4¾	5¼	5¾	6½	7¼	8	8½	9	9¾	10¼	

MILLING HEART-SHAPED CAMS

One method of producing heart-shaped cams is as follows:

Lay out the curve of the cam roughly, as in Fig. 9. Drill and remove the outside stock, being sure to leave sufficient stock to overcome errors in laying out. Put the cam on the nut arbor and tighten securely. If the roll of the cam is $\frac{1}{8}$ radius, select a milling cutter having the same radius, as the roll of the cam must come to the lowest point, which it would not be able to do if a cutter of a smaller radius than that of the roll were used. It would also make a difference to the other points on the curve of the cam, which is not quite so apparent at first glance.



Fig. 9.—Method of Laying Out Cam

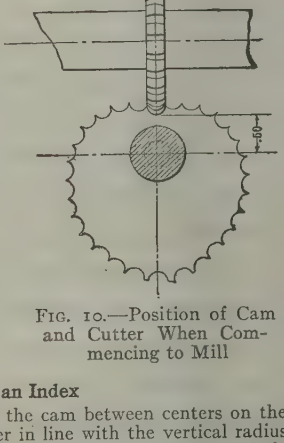


Fig. 10.—Position of Cam and Cutter When Commencing to Mill

Selecting an Index

The next operation is to place the cam between centers on the milling machine, having the cutter in line with the vertical radius of the cam, at its lowest point. Next choose an index circle which will give a division of the cam such that the rise of each division will be in thousandths of an inch, if possible. For this cam take a circle which will give 200 divisions. As this will make 100 divisions on a side, the rise of each division will be 0.011 of an inch. Now raise the table to the required height, starting at the lowest point of the cam, and mill across, as in Fig. 10.

Moving the Table

For the other cuts lower the table 0.011 each time, and revolve the cam one division until the highest point of the cam is reached, then raise the table 0.011 for each division of the cam.

When the cam comes from the milling machine there will be found to be small grooves left between the cuts. These may be easily

removed by smoothing off with a file without impairing the accuracy of the cam.

Most screw-machine cams can be made in this manner, and they will be found to be more accurate than if laid out and filed to the line, and also much easier to make after one has become accustomed to the method.

MILLING CAMS BY GEARING UP THE DIVIDING HEAD

By the method here shown, cams of any rise may be milled with the gears regularly furnished with the milling-machine.

With the head set vertically the lead of the cam would be the same as the lead for which the machine is geared, while with the head horizontal and the milling spindle also, a concentric arc, or rest, would be milled on the cam, regardless of how the machine was geared. By inclining the head and milling spindle, we can produce any lead on the cam less than that for which the machine is geared.

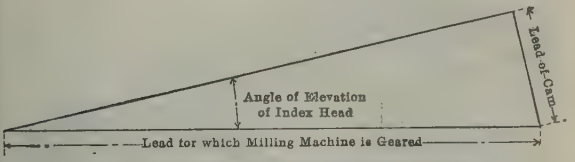


FIG. 11.—Diagram for Angle of Index Head

The method of finding the inclination at which to set the index head is shown in Fig. 11, and is simply the solution of a plain right angled triangle, in which the hypothenuse represents the lead of the machine, and one of the other sides represents the lead we wish to produce on the cam. By dividing the latter by the former we get the sine of the angle of inclination.

Take for illustration a plate cam having $\frac{1}{8}$-inch rise in 300 degrees.

$$\frac{360}{300} \times \frac{1}{8} = 0.15,$$

which is the lead we want on the cam, while the slowest lead for which the B. & S. machine can be geared is 0.67

$$\frac{0.15}{0.67} = 0.224.$$

Consulting a table of sines, we find 0.224 approximates closely the sine of 13 degrees, which is the angle at which to set the head, and if the milling spindle is also set at the same angle, the edge of the cam will be parallel with the shaft on which it is to run. Fig. 12 shows a milling-machine set for this job.

When a cam has several lobes of different leads, we gear the machine up for a lead somewhat longer than the longest one called for in that cam, and then all the different lobes can be milled with the one setting of gears, by simply altering the inclination of head and milling spindle for each different lead on the cam.

If the diameter of the cam and the inclination of the head will admit, it is better to mill on the under side of the cam, as that brings the mill and the table nearer together and thus increases rigidity, besides enabling us to easily see any lines that may be laid out on the flat face of the cam. Also the chips do not accumulate on the work.

The work is fed against the cutter by turning the index crank, and on coming back for another cut we turn the handle of the mill-

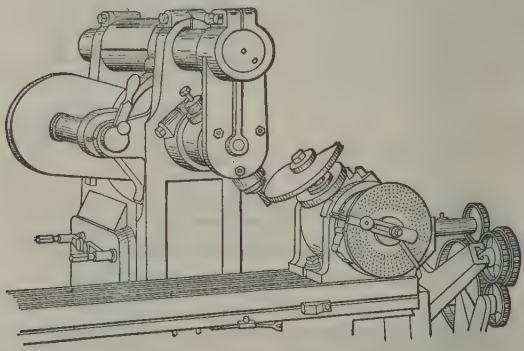


FIG. 12.—Milling Cams

ing-machine table. As a result the work will recede from the cutter before the cam blank commences to turn, owing to back lash in the gears, thus preventing the cutter from dragging over the work while running back.

In this way we use to advantage what is ordinarily considered a defect in machine construction.

The milling-machine, when used as shown in Fig. 4, will be found to be more rigid than when the head is set in the vertical position, and the cams will work more smoothly on account of the shearing action of the cutter.

One possible objection to the method here advocated is the necessity of using, in some cases, an end mill of extra length of tooth. In practice, an end mill $\frac{7}{8}$-inch diameter and with a $3\frac{1}{2}$-inch length of tooth is not unusual; but the results in both speed and quality will be found entirely satisfactory.

TABLES OF SETTINGS FOR MILLING SCREW MACHINE CAMS

The accompanying table is for finding the angles used in milling Browne & Sharpe automatic screw machine cams. It is designed to reduce the number of gear changes to a minimum, only eight leads being given. Leads above 6 inches are omitted, since the theoretically perfect rise of a Brown & Sharpe screw machine cam is not a spiral and with steep rises this difference becomes so pronounced that the geometrical error far exceeds any errors usual to working the rise by hand, and the hand work is probably the cheapest.

The operation of the table will be largely self-evident. The column at the left gives the cam rise for a complete revolution of the cam or the rise of lobe $\times$ 100 inches $\div$ number of hundredths in lobe. For example, we have a lobe covering eight hundredths and having a rise of 0.375 inch. Therefore $\frac{0.375 \times 100}{8} = 4.6875$ inches or the rise per complete revolution. The nearest rise to 4.6875 inches occurring in the table is 4.750 inches. This will usually be near enough, but if for any reason greater accuracy is required, interpolation may be resorted to.

In finding the angles for a set of cams one should first find the complete rises of all the lobes. It is then a simple matter to assign as many of these rises to any one lead as come within the range of that lead, spreading the whole over as few leads as possible.

These tables advance by cam lead differences of 0.005 up to 1 inch; then by 0.010 inch up to 1.5 inch; then by 0.025 and larger increments to 6 inches. It is believed that the simple method of figuring for all intermediate steps as explained on pages 163 and 166 will enable the reader to make full use of this method of setting for cam milling without the necessity of making many gear changes for dividing head leads, as eight leads in the tables cover the range of cam leads or rises from 0.005 to 6 inches.

Angle between Arbor and Table

Rise in a Complete Rev. of Cam	Lead of Mach. 0.670 Inch		Lead of Mach. 1.050 Inch		Lead of Mach. 1.500 Inch		Lead of Mach. 2.000 Inches		Lead of Mach. 3.000 Inches		Lead of Mach. 4.000 Inches		Lead of Mach. 5.000 Inches		Lead of Mach. 6.000 Inches	
	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.
0.005	0	26														
0.010	0	51														
0.015	1	17														
0.020	1	43														
0.025	2	08														
0.030	2	34														
0.035	3	00														
0.040	3	25														
0.045	3	51														
0.050	4	17														
0.055	4	43														
0.060	5	08														
0.065	5	34														
0.070	6	00														
0.075	6	26														
0.080	6	51														
0.085	7	17														
0.090	7	43														
0.095	8	09														
0.100	8	35														
0.105	9	01														
0.110	9	27														
0.115	9	53														
0.120	10	19														
0.125	10	45														
0.130	11	11														
0.135	11	38														
0.140	12	04														
0.145	12	30														
0.150	12	56														
0.155	13	23														
0.160	13	49														
0.165	14	15														
0.170	14	42														
0.175	15	08														
0.180	15	35														
0.185	16	02														
0.190	16	28														
0.195	16	58														
0.200	17	22														
0.205	17	49														
0.210	18	16														
0.215	18	43														
0.220	19	10														
0.225	19	37														
0.230	20	05														
0.235	20	32														
0.240	20	59														
0.245	21	27														
0.250	21	55														
0.255	22	22														
0.260	22	50	14	20												
0.265	23	18	14	37												
0.270	23	46	14	54												
0.275	24	14	15	11												

Angle between Arbor and Table

Rise in a Complete Rev. of Cam	Lead of Mach. 0.670 Inch		Lead of Mach. 1.050 Inch		Lead of Mach. 1.500 Inch		Lead of Mach. 2.000 Inches		Lead of Mach. 3.000 Inches		Lead of Mach. 4.000 Inches		Lead of Mach. 5.000 Inches		Lead of Mach. 6.000 Inches	
	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.
0.280	24	42	15	28												
0.285	25	10	15	45												
0.290	25	39	16	02												
0.295	26	07	16	19												
0.300	26	36	16	36												
0.305	27	05	16	53												
0.310	27	34	17	10												
0.315	28	03	17	27												
0.320	28	32	17	45												
0.325	29	01	18	02												
0.330	29	30	18	19												
0.335	30	00	18	36												
0.340	30	30	18	54												
0.345	30	59	19	11												
0.350	31	30	19	28												
0.355	32	00	19	46												
0.360	32	30	20	04												
0.365	33	01	20	21												
0.370	33	31	20	38												
0.375	34	02	20	55												
0.380	34	33	21	13												
0.385	35	04	21	31												
0.390	35	36	21	48												
0.395	36	07	22	06												
0.400	36	39	22	24												
0.405	37	12	22	41												
0.410	37	44	22	59												
0.415	38	16	23	17												
0.420	38	49	23	35												
0.425	39	22	23	53												
0.430	39	55	24	11												
0.435	40	29	24	28												
0.440	41	03	24	46												
0.445	41	37	25	05												
0.450	42	12	25	23												
0.455	42	47	25	41												
0.460	43	22	25	59												
0.465	43	57	26	17												
0.470	44	32	26	35												
0.475	45	09	26	54												
0.480	45	46	27	12												
0.485	46	23	27	31												
0.490	47	00	27	49												
0.495	47	38	28	07												
0.500	48	16	28	26	19	28										
0.505	48	55	28	45	19	40										
0.510	49	34	29	04	19	53										
0.515	50	14	29	23	20	05										
0.520	50	55	29	41	20	17										
0.525	51	35	30	00	20	29										
0.530	52	27	30	19	20	41										
0.535	52	59	30	39	20	54										
0.540	53	43	30	57	21	06										
0.545	54	26	31	16	21	18										
0.550	55	11	31	35	21	31										

Angle between Arbor and Table

Rise in a Complete Rev. of Cam	Lead of Mach. 0.670 Inch		Lead of Mach. 1.050 Inch		Lead of Mach. 1.500 Inch		Lead of Mach. 2.000 Inches		Lead of Mach. 3.000 Inches		Lead of Mach. 4.000 Inches		Lead of Mach. 5.000 Inches		Lead of Mach. 6.000 Inches	
	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.
0.555	55	50	31	55	21	43										
0.560	56	42	32	14	21	55										
0.565	57	30	32	33	22	08										
0.570	58	18	32	53	22	20										
0.575	59	07	33	12	22	33										
0.580	59	58	33	32	22	45										
0.585	60	50	33	52	22	57										
0.590	61	43	34	12	23	10										
0.595	62	38	34	31	23	22										
0.600	63	35	34	51	23	35	17	27								
0.605	64	34	35	11	23	47	17	37								
0.610	65	33	35	31	24	00	17	46								
0.615	66	41	35	51	24	13	17	54								
0.620	67	54	36	12	24	25	18	04								
0.625	68	53	36	31	24	37	18	13								
0.630	70	06	36	52	24	50	18	22								
0.635	71	24	37	13	25	03	18	31								
0.640	72	48	37	33	25	15	18	40								
0.645	74	17	37	55	25	28	18	49								
0.650	75	58	38	15	25	40	18	58								
0.655	77	51	38	36	25	53	19	07								
0.660	80	06	38	57	26	06	19	16								
0.665	83	00	39	18	26	19	19	25								
0.670	90	00	39	39	26	32	19	34								
0.675			40	00	26	45	19	43								
0.680			40	22	26	57	19	53								
0.685			40	43	27	10	20	02								
0.690			41	05	27	23	20	11								
0.695			41	27	27	36	20	20								
0.700			41	49	27	49	20	29								
0.705			42	11	28	02	20	38								
0.710			42	33	28	15	20	48								
0.715			42	55	28	27	20	57								
0.720			43	17	28	40	20	06								
0.725			43	40	28	53	21	15								
0.730			44	03	29	07	21	24								
0.735			44	26	29	21	21	34								
0.740			44	49	29	34	21	43								
0.745			45	12	29	47	21	52								
0.750			45	35	30	00	22	02								
0.755			45	58	30	13	22	11								
0.760			46	22	30	27	22	20								
0.765			46	46	30	40	22	29								
0.770			47	10	30	53	22	39								
0.775			47	34	31	06	22	48								
0.780			47	59	31	20	22	57								
0.785			48	23	31	34	23	07								
0.790			48	48	31	47	23	16								
0.795			49	13	32	00	23	25								
0.800			49	38	32	14	23	35								
0.805			50	03	32	27	23	44								
0.810			50	29	32	41	23	54								
0.815			50	55	32	55	24	03								
0.820			51	21	33	08	24	12								
0.825			51	47	33	22	24	22								

Angle between Arbor and Table

Rise in a Complete Rev. of Cam	Lead of Mach. 0.670 Inch		Lead of Mach. 1.050 Inch		Lead of Mach. 1.500 Inch		Lead of Mach. 2.000 Inches		Lead of Mach. 3.000 Inches		Lead of Mach. 4.000 Inches		Lead of Mach. 5.000 Inches		Lead of Mach. 6.000 Inches	
	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.
0.830			52	14	33	36	24	31								
0.835			52	41	33	49	24	41								
0.840			53	08	34	03	24	50								
0.845			53	36	34	17	25	00								
0.850			54	03	34	31	25	09								
0.855			54	31	34	45	25	19								
0.860			55	00	34	59	25	28								
0.865			55	28	35	13	25	38								
0.870			55	57	35	27	25	47								
0.875			56	26	35	41	25	57								
0.880			56	56	35	55	26	06								
0.885			57	27	36	10	26	16								
0.890			57	58	36	24	26	25								
0.895			58	29	36	38	26	35								
0.900			59	00	36	52	26	45								
0.905			59	32	37	07	26	54								
0.910			60	06	37	21	27	04								
0.915			60	38	37	35	27	13								
0.920			61	11	37	50	27	23								
0.925			61	46	38	04	27	33								
0.930			62	20	38	19	27	43								
0.935			62	57	38	33	27	52								
0.940			63	33	38	48	28	02								
0.945			64	11	39	03	28	12								
0.950			64	49	39	18	28	22								
0.955			65	26	39	33	28	31								
0.960			66	06	39	47	28	41								
0.965			66	48	40	02	28	51								
0.970			67	30	40	17	29	01								
0.975			68	13	40	32	29	11								
0.980			68	54	40	47	29	20								
0.985			69	45	41	01	29	30								
0.990			70	32	41	17	29	40								
0.995			71	23	41	33	29	50								
1.000			72	15	41	49	30	00	19	28						
1.010			74	08	42	20	30	20	19	40						
1.020			76	16	42	50	30	40	19	53						
1.030			78	48	43	23	31	00	20	05						
1.040			82	05	43	54	31	20	20	17						
1.050			90	00	44	27	31	40	20	29						
1.060					44	57	32	00	20	41						
1.070					45	30	32	20	20	54						
1.080					46	04	32	41	21	06						
1.090					46	36	33	01	21	18						
1.100					47	10	33	22	21	30						
1.110					47	44	33	43	21	43						
1.120					48	18	34	03	21	55						
1.130					48	53	34	24	22	07						
1.140					49	28	34	45	22	20						
1.150					50	03	35	06	22	33						
1.160					50	39	35	27	22	45						
1.170					51	16	35	48	22	58						
1.180					51	53	36	09	23	10						
1.190					52	30	36	31	23	22						
1.200					53	08	36	52	23	35						

Angle between Arbor and Table

Rise in a Complete Rev. of Cam	Lead of Mach. 0.670 Inch		Lead of Mach. 1.050 Inch		Lead of Mach. 1.500 Inch		Lead of Mach. 2.000 Inches		Lead of Mach. 3.000 Inches		Lead of Mach. 4.000 Inches		Lead of Mach. 5.000 Inches		Lead of Mach. 6.000 Inches	
	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.
1.210					53	46	37	14	23	47						
1.220					54	25	37	35	23	59						
1.230					55	05	37	57	24	12						
1.240					55	45	38	19	24	25						
1.250					56	26	38	41	24	37	18	13				
1.260					57	08	39	03	24	50	18	22				
1.270					57	51	39	25	25	03	18	31				
1.280					58	34	39	48	25	15	18	40				
1.290					59	19	40	09	25	28	18	49				
1.300					60	04	40	32	25	41	18	58				
1.310					60	51	40	55	25	53	19	07				
1.320					61	38	41	18	26	06	19	16				
1.330					62	28	41	41	26	19	19	25				
1.340					63	17	42	04	26	32	19	34				
1.350					64	10	42	27	26	45	19	43				
1.360					65	03	42	50	26	57	19	53				
1.370					65	59	43	14	27	10	20	02				
1.380					66	56	43	38	27	23	20	11				
1.390					67	55	44	02	27	36	20	20				
1.400					68	49	44	25	27	49	20	29				
1.410					70	03	44	50	28	02	20	39				
1.420					71	12	45	14	28	15	20	48				
1.430					72	26	45	39	28	28	20	57				
1.440					73	45	46	03	28	41	21	06				
1.450					75	09	46	28	28	54	21	15				
1.460					76	45	46	53	29	07	21	24				
1.470					78	31	47	18	29	20	21	34				
1.480					80	38	47	44	29	33	21	43				
1.490					83	23	48	10	29	46	21	52				
1.500					90	00	48	36	30	00	22	02				
1.525							49	41	30	32	22	24				
1.550							50	48	31	06	22	48				
1.575							51	57	31	40	23	11				
1.600							53	09	32	14	23	35	18	40		
1.625							54	23	32	48	23	58	18	58		
1.650							55	39	33	22	24	21	19	16		
1.675							56	52	33	56	24	45	19	34		
1.700							58	12	34	31	25	09	19	52		
1.725							59	36	35	06	25	33	20	11		
1.750							61	03	35	41	25	57	20	29		
1.775							62	34	36	16	26	21	20	48		
1.800							64	10	36	52	26	45	21	06		
1.825							65	51	37	28	27	09	21	24		
1.850							67	40	38	04	27	33	21	43		
1.875							69	38	38	41	27	57	22	02		
1.900							71	49	39	16	28	21	22	20		
1.925							74	16	39	55	28	46	22	39		
1.950							77	10	40	33	29	10	22	57		
1.975							80	56	41	11	29	35	23	16		
2.000							90	00	41	49	30	00	23	35	19	2
2.100									44	26	31	40	24	50	20	2
2.200									47	10	33	22	26	06	21	3
2.300									50	03	35	06	27	23	22	3
2.400									53	08	36	52	28	41	23	3

ANGLE BETWEEN ARBOR AND TABLE

Rise in a Complete Rev. of Cam	Lead of Mach. 0.670 Inch		Lead of Mach. 1.050 Inch		Lead of Mach. 1.500 Inch		Lead of Mach. 2.000 Inches		Lead of Mach. 3.000 Inches		Lead of Mach. 4.000 Inches		Lead of Mach. 5.000 Inches		Lead of Mach. 6.000 Inches	
	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.	Degs.	Min.
2.500									56	24	38	41	30	00	24	37
2.600									60	04	40	32	31	20	25	41
2.700									64	09	42	27	32	41	26	45
2.800									68	58	44	25	34	03	27	49
2.900									75	09	46	28	35	27	28	53
3.000									90	00	48	36	36	52	30	00
3.100											50	48	38	19	31	08
3.200											53	08	39	47	32	22
3.300											55	35	41	18	33	22
3.400											58	13	42	51	34	31
3.500											61	03	44	26	35	41
3.600											64	09	46	03	36	52
3.700											67	40	47	44	38	04
3.800											71	49	49	28	39	18
3.900											77	10	51	16	40	33
4.000											90	00	53	07	41	49
4.250													58	12	45	09
4.500													64	10	48	36
4.750													71	49	52	20
5.000													90	00	56	26
5.250															61	03
5.500															66	26
5.550															73	24
6.000															90	00

Other Tables for Milling Cams

The following tables computed by the Cincinnati Milling Machine Co. will be also found very useful.

These tables give all the information necessary and it only remains for the milling machine operator to select the lead of the desired cam from the tables and set up for the corresponding change gears and angles.

In setting the vertical milling attachment read the angle direct from the dial. Example: if the angle given in the table is $39\frac{1}{2}$ degrees, set the spindle $39\frac{1}{2}$ degrees from its vertical position.

In setting the dividing head, subtract the angle in the table from 90 degrees. The difference represents the angle to which the dividing head spindle must be raised from the horizontal position.

Example: The angle given in the table is $39\frac{1}{2}$ degrees. 90 degrees $-39\frac{1}{2}$ degrees equals $50\frac{1}{2}$ degrees.

Set the dividing head spindle $50\frac{1}{2}$ degrees up from the horizontal position. This angle is read direct from the dial. The set up is shown in Fig. 12.

The tables may of course be used in connection with the cutting of any other similar cams.

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
.600	24	86	24	100	26½
.601	24	86	24	100	26
.602	24	86	24	100	26
.603	24	86	28	100	30½
.604	24	72	24	100	41
.605	24	86	24	100	25½
.606	24	86	28	100	39
.607	24	86	24	100	25
.608	24	72	24	100	40½
.609	24	86	24	100	24½
.610	24	86	24	100	24½
.611	24	86	28	100	38½
.612	24	86	24	100	24
.613	24	72	24	100	40
.614	24	86	24	100	23⅓
.615	24	86	28	100	38
.616	24	86	24	100	23
.617	24	72	24	100	30½
.618	24	72	24	100	30½
.619	24	86	24	100	22½
.620	24	86	28	100	37½
.621	24	86	24	100	22
.622	24	72	24	100	30
.623	24	86	24	100	21½
.624	24	86	28	100	37
.625	24	86	24	100	21
.626	24	86	32	100	45½
.627	24	86	24	100	20½
.628	24	86	28	100	36½
.629	24	86	24	100	20
.630	24	72	24	100	38
.631	24	86	32	100	45
.632	24	86	28	100	36
.633	24	86	24	100	19
.634	24	72	24	100	37½
.635	24	86	24	100	18½
.636	24	86	28	100	35½
.637	24	86	32	100	44½
.638	24	72	24	100	37
.639	24	86	24	100	17½
.640	24	86	28	100	35
.641	24	86	24	100	17
.642	24	86	32	100	44
.643	24	86	28	100	34½
.644	24	86	24	100	16
.645	24	86	24	100	15½
.646	24	86	24	100	15½
.647	24	86	24	100	15
.648	24	86	32	100	43½
.649	24	86	24	100	14½
.650	24	86	24	100	14
.653	24	86	32	100	43
.654	24	86	24	100	12½
.655	24	86	24	100	12
.656	24	86	24	100	11½
.657	24	86	24	100	11
.658	24	86	32	100	42½
.659	24	72	24	100	34½
.660	24	86	24	100	10
.661	24	86	28	100	32
.662	24	86	28	100	32
.663	24	72	24	100	34
.664	24	86	32	100	42
.665	24	72	28	100	41½
.666	24	86	28	100	31½
.667	24	72	24	100	33½
.668	24	64	24	100	42
.669	24	72	24	86	44
.670	24	86	28	100	31
.671	24	72	24	100	33
.672	24	86	28	100	30½
.673	24	86	28	100	30½
.674	24	64	24	100	41½
.675	24	72	24	100	32½
.676	24	86	28	100	30
.677	24	72	28	100	43⅓
.678	24	72	24	100	32
.679	24	86	32	100	40½
.680	24	72	24	86	43
.681	24	72	24	100	31½
.682	24	72	28	100	43
.683	24	86	28	100	29
.684	24	86	32	100	40
.685	24	72	24	86	42½
.686	24	86	28	100	28½
.687	24	72	28	100	42½
.688	24	72	28	100	42½
.689	24	86	32	100	39½
.690	24	86	28	100	28
.691	24	72	24	86	42
.692	24	86	28	100	27½
.693	24	72	28	100	42
.694	24	86	32	100	39
.695	24	64	24	100	30½
.696	24	86	28	100	27
.697	24	72	24	86	41½
.698	24	72	28	100	41½
.699	24	86	32	100	38½
.700	24	72	24	100	29
.701	24	72	24	86	41
.702	24	86	28	100	26
.703	24	72	24	100	28
.704	24	86	32	100	38
.705	24	86	28	100	25
.706	24	72	24	100	28
.707	24	72	24	86	40
.708	24	86	28	100	25
.709	24	72	28	100	40
.710	24	72	24	100	27
.711	24	86	28	100	24
.712	24	72	24	86	40
.713	24	72	24	100	27
.714	24	64	24	100	37
.715	24	72	28	100	40
.716	24	86	28	100	23
.717	24	72	24	86	39
.718	24	86	32	100	36
.719	24	86	28	100	23
.720	24	72	28	100	39
.721	24	86	28	100	22
.722	24	72	24	100	25
.723	24	64	24	100	36
.724	24	86	28	100	22
.725	24	72	24	100	25
.726	24	86	28	100	21
.727	24	86	32	100	35
.728	24	72	24	100	24
.729	24	86	28	100	21
.730	24	72	28	100	38
.731	24	72	24	100	24
.732	24	86	28	100	20
.733	24	72	24	86	38
.734	24	86	28	100	20
.735	24	72	28	100	38
.736	24	86	28	100	19
.737	24	64	24	100	35
.738	24	72	24	86	37
.739	24	72	24	100	22
.740	24	72	28	100	37
.741	24	86	28	100	18
.742	24	72	24	100	22
.743	24	86	28	100	18
.744	24	72	24	100	21
.745	24	72	28	100	37
.746	24	64	24	100	34
.747	24	86	28	100	17
.748	24	72	24	86	36
.749	24	86	28	100	16½

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
.750	24	72	28	100	36½
.751	24	86	28	100	16
.752	24	72	24	100	20
.753	24	86	32	100	32½
.754	24	72	24	100	19⅜
.755	24	72	28	100	36
.756	24	86	28	100	14⅛
.757	24	72	24	86	35
.758	24	86	28	100	14
.759	24	64	24	100	32
.760	24	72	28	100	35⅝
.761	24	86	28	100	13
.762	24	72	24	86	35
.763	24	72	24	100	17½
.764	24	86	28	100	12
.765	24	72	24	100	17
.766	24	72	24	86	34⅜
.767	24	72	24	100	16⅞
.768	24	86	28	100	10½
.769	24	86	28	100	10
.770	24	86	32	100	30⅛
.771	24	72	24	86	34
.772	24	72	24	100	15
.773	24	86	32	100	30
.774	24	72	24	100	14⅜
.775	24	64	24	100	30½
.776	24	72	24	100	14
.777	24	86	32	100	29⅝
.778	24	72	28	100	33½
.779	24	72	24	100	13
.780	24	72	24	86	33
.781	24	72	24	100	12⅛
.782	24	72	28	100	33
.783	24	64	24	100	29½
.784	24	72	24	100	11⅝
.785	24	86	32	100	28¼
.786	28	86	32	100	41
.787	24	64	24	100	29
.788	24	72	24	100	10
.789	24	72	24	86	32
.790	24	64	24	86	41
.791	24	64	24	100	28½
.792	24	86	32	100	27½
.793	24	72	24	86	31⅛
.794	24	72	28	86	43
.795	24	72	28	100	31⅛
.796	24	64	24	86	40½
.797	24	72	24	86	31
.798	28	86	32	100	40
.799	24	72	32	100	41⅛
.800	24	72	28	100	31
.801	24	72	24	86	30⅛
.802	24	64	24	86	40
.803	24	86	32	100	26
.804	28	86	32	100	39½
.805	24	72	32	100	41
.806	24	86	32	100	25⅝
.807	24	64	24	86	39⅝
.808	24	72	28	100	30
.809	24	64	24	100	26
.810	28	86	32	100	39
.811	24	72	32	100	40½
.812	24	72	28	100	29⅜
.813	24	72	24	86	29
.814	24	64	24	86	39
.815	28	86	32	100	38⅛
.816	24	72	28	100	29
.817	24	72	24	86	28½
.818	24	72	28	86	41
.819	24	86	32	100	23¼
.820	24	72	28	100	28⅛
.821	24	72	24	86	28
.822	24	86	32	100	23
.823	24	72	32	100	39⅛
.824	24	72	28	100	28
.825	24	72	24	86	27⅝
.826	28	86	32	100	37½
.827	24	72	28	100	27⅛
.828	24	86	32	100	22
.829	24	86	40	100	42
.830	24	64	24	86	37⅜
.831	24	72	28	86	40
.832	24	72	24	86	26½
.833	24	56	24	100	36
.834	24	86	32	100	21
.835	24	72	32	100	38⅛
.836	24	72	24	86	26
.837	24	72	28	86	39⅛
.838	24	56	24	100	35½
.839	24	86	32	100	20
.840	24	64	24	100	21
.841	24	72	32	100	38
.842	24	86	32	100	19½
.843	24	72	28	86	39
.844	24	86	32	100	19
.845	24	72	28	100	25
.846	24	64	24	100	20
.847	24	86	32	100	18⅜
.848	24	64	24	100	19½
.849	24	86	32	100	18
.850	24	72	24	86	24
.851	24	72	28	100	24
.852	24	64	24	100	19
.853	24	72	24	86	23½
.854	24	86	32	100	17
.855	24	64	28	100	35½
.856	24	86	32	100	16½
.857	24	64	24	86	35
.858	24	64	24	100	17½
.859	24	72	24	86	22½
.860	24	64	28	100	35
.861	24	72	28	86	37⅛
.862	24	72	28	100	22½
.863	24	64	24	100	16½
.864	28	86	32	100	34
.865	24	64	24	100	16
.866	24	86	32	100	14
.867	24	64	24	100	15⅜
.868	24	72	28	100	21½
.869	24	64	24	100	15
.870	24	86	32	100	13
.871	24	64	24	100	14⅜
.872	24	86	32	100	12½
.873	24	64	24	100	14
.874	24	72	24	80	20
.875	24	86	32	100	11⅜
.876	24	64	28	100	33½
.877	24	64	24	100	13
.878	24	86	32	100	10½
.879	24	64	24	100	12½
.880	24	64	24	100	12
.881	24	64	28	100	33
.882	24	64	24	100	11½
.883	24	64	24	86	32½
.884	28	86	32	100	32
.885	24	64	24	100	10⅜
.886	24	64	24	100	10
.887	24	72	24	86	17½
.888	24	64	24	86	32
.889	24	72	24	86	17
.890	24	72	28	100	17½
.891	24	56	24	100	30
.892	24	72	24	86	16½
.893	28	86	32	100	31
.894	24	72	24	86	16
.895	24	64	28	100	31½
.896	24	72	24	86	15½
.897	24	72	28	100	16
.898	24	72	24	86	15
.899	24	72	28	100	15½

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
.900	24	56	24	100	29
.901	24	72	28	100	15
.902	24	72	24	86	14
.903	24	72	28	100	14 11/16
.904	24	72	24	86	13 1/2
.905	24	72	28	100	14
.906	24	72	24	86	13
.907	24	72	28	100	13 1/16
.908	24	72	24	86	12 11/16
.909	24	72	28	100	13
.910	24	72	32	100	31 1/2
.911	24	72	28	100	12 3/4
.912	24	72	28	100	12
.913	24	72	24	86	11
.914	24	72	28	100	11 1/2
.915	24	72	32	100	31
.916	24	72	24	86	10
.917	24	72	28	100	10 1/4
.918	24	64	28	100	29
.919	24	72	28	100	10
.920	28	86	32	100	28
.921	24	56	24	100	26 1/2
.922	24	64	28	86	41
.923	24	64	28	100	28 1/2
.924	28	86	32	100	27 1/2
.925	24	56	24	100	26
.926	24	64	32	100	39 1/2
.927	24	64	28	100	28
.928	24	64	28	86	40 1/2
.929	24	56	24	100	25 3/4
.930	24	72	28	86	31
.931	24	64	28	100	27 1/2
.932	28	72	32	100	41 1/2
.933	24	64	24	86	27
.934	24	86	44	100	40 1/2
.935	24	72	28	86	30 1/2
.936	24	56	24	100	24 3/4
.937	24	64	24	86	26
.938	24	72	32	100	28 3/4
.939	24	64	32	100	38 1/2
.940	24	56	24	100	24
.941	24	64	24	86	26
.942	24	72	32	100	28
.943	24	72	32	86	40 3/4
.944	24	56	24	100	23 3/4
.945	24	64	24	86	25 1/2
.946	24	72	32	100	27 1/2
.947	24	56	24	100	23
.948	28	86	32	100	24 3/4
.949	24	64	24	86	25
.950	24	72	32	86	40
.951	24	56	24	100	22 1/2
.952	28	86	32	100	24
.953	24	64	24	86	24 1/2
.954	24	56	24	100	22
.955	24	72	32	100	26 1/2
.956	24	64	28	86	38 1/2
.957	24	56	24	100	21 1/2
.958	24	72	28	86	28
.959	24	72	32	100	26
.960	24	64	24	86	23 1/2
.961	28	86	44	100	38 1/2
.962	24	72	28	86	27 1/2
.963	28	86	32	100	22 1/2
.964	24	56	24	100	20 1/2
.965	24	64	32	100	36 1/2
.966	28	86	32	100	22
.967	24	56	24	100	20
.968	24	56	24	86	36
.969	24	64	28	86	37 1/2
.970	24	56	24	100	19 1/2
.971	24	72	28	86	26 1/2
.972	86	44	32	64	6
.973	24	56	24	100	19
.974	24	64	24	86	21 1/2
.975	24	72	32	100	24
.976	28	86	32	100	20 1/2
.977	24	64	28	100	21 1/2
.978	24	56	24	100	18
.979	28	86	32	100	20
.980	24	64	28	100	21
.981	24	64	24	86	20 1/2
.982	28	86	32	100	19 1/2
.983	24	72	28	86	25
.984	24	56	24	100	17
.985	28	86	32	100	19
.986	24	72	32	100	22 1/2
.987	24	64	24	86	19 3/4
.988	28	86	32	100	18 1/2
.989	24	56	24	100	16
.990	24	64	24	86	19
.991	28	86	32	100	18
.992	24	56	24	100	15 1/2
.993	24	64	24	86	18 1/2
.994	24	56	24	100	15
.995	24	72	28	86	23 1/2
.996	24	56	24	100	14 1/2
.997	24	56	24	86	33 1/2
.998	24	56	24	100	14
.999	28	86	32	100	16 1/2
1.000	24	86	44	100	35
1.001	24	56	24	100	13
1.002	28	86	32	100	16
1.003	24	56	24	100	13
1.004	28	86	32	100	15
1.005	24	56	24	100	12
1.006	24	56	24	100	12
1.007	24	64	24	86	10
1.008	24	56	24	100	11
1.009	28	86	32	100	14
1.010	24	56	24	100	11
1.011	28	86	32	100	14
1.012	24	56	24	100	10
1.013	24	56	24	100	10
1.014	24	64	24	86	14
1.015	28	86	32	100	13
1.016	24	64	24	86	14
1.017	28	86	32	100	12
1.018	24	64	24	86	13
1.019	28	86	32	100	12
1.020	24	64	24	86	13
1.021	28	86	32	100	11
1.022	24	64	24	86	12
1.023	28	86	32	100	11
1.024	24	64	24	86	12
1.025	24	64	28	100	12
1.026	24	64	24	86	11
1.027	24	64	28	100	12
1.028	24	64	24	86	11
1.029	24	64	28	100	11
1.030	24	64	24	86	10
1.031	24	64	28	100	11
1.032	24	64	28	100	10
1.033	24	72	32	100	14
1.034	24	64	28	100	10
1.035	24	72	32	100	14
1.036	24	56	24	86	30
1.037	24	72	32	100	13
1.038	24	72	28	86	17
1.039	24	64	32	100	30
1.040	24	72	32	100	13
1.041	24	56	24	86	20
1.042	24	72	32	100	12
1.043	24	72	28	86	16
1.044	24	72	32	100	12
1.045	24	86	40	100	20
1.046	24	72	32	100	11
1.047	24	72	32	100	11
1.048	24	72	28	86	15
1.049	24	72	32	100	10

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle	Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle	Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
1.050	24	72	28	86	14½	1.150	23	56	24	86	16	1.250	24	64	28	72	31
1.052	24	86	40	100	19½	1.152	28	86	44	100	36½	1.252	28	86	40	100	16
1.054	24	72	28	86	14	1.154	24	64	28	86	19	1.254	24	64	32	86	26
1.056	24	56	24	86	28	1.156	24	64	32	100	15½	1.256	24	64	28	72	30½
1.058	24	86	40	100	18½	1.158	24	56	24	86	14½	1.258	28	86	40	100	15
1.060	28	86	40	100	35½	1.160	24	56	24	86	14	1.260	28	86	40	100	14½
1.062	24	72	28	86	12	1.162	24	64	32	100	14½	1.262	32	56	24	100	23
1.064	24	86	40	100	17½	1.164	24	64	32	100	14	1.264	24	72	40	100	18½
1.066	24	56	24	86	27	1.166	24	72	40	100	29	1.266	28	86	40	100	13½
1.068	24	64	28	86	29	1.168	24	56	24	86	12½	1.268	24	72	40	100	18
1.070	24	86	40	100	16½	1.170	24	56	24	86	12	1.270	24	72	44	100	30
1.072	28	72	32	100	30½	1.172	24	56	24	86	11½	1.272	28	72	32	86	28½
1.074	24	64	32	100	26½	1.174	24	56	24	86	11	1.274	28	86	40	100	12
1.076	24	64	32	86	39½	1.176	24	56	24	86	10½	1.276	28	86	40	100	11½
1.078	24	86	40	100	15	1.178	24	56	24	86	10	1.278	28	86	40	100	11
1.080	24	86	40	100	14½	1.180	24	64	32	100	10½	1.280	28	86	40	100	10½
1.082	28	86	44	100	41	1.182	24	64	32	100	10	1.282	28	86	40	100	10
1.084	24	56	24	86	25	1.184	24	64	32	100	9½	1.284	24	72	40	100	15½
1.086	28	86	40	100	33½	1.186	24	86	44	100	15	1.286	40	64	24	100	31
1.088	24	56	24	86	24½	1.188	24	72	40	100	27	1.288	24	72	40	100	15
1.090	24	72	32	86	28½	1.190	24	64	28	86	13	1.290	24	72	40	100	14½
1.092	24	86	40	100	12	1.192	24	64	28	86	12½	1.292	32	56	24	100	19½
1.094	24	86	40	100	11½	1.194	24	64	28	86	12	1.294	24	86	48	100	15
1.096	24	86	40	100	11	1.196	28	72	32	100	16	1.296	24	72	40	100	13½
1.098	28	72	32	100	28	1.198	24	72	32	86	15	1.298	24	64	32	86	21½
1.100	28	72	32	86	40½	1.200	24	72	32	86	14½	1.300	24	86	48	100	14
1.102	24	64	28	86	25½	1.202	24	64	28	86	10	1.302	24	64	32	86	21
1.104	24	86	44	100	26	1.204	28	72	32	100	14½	1.304	24	72	40	100	12
1.106	40	64	24	100	42½	1.206	24	72	32	86	13½	1.306	24	72	40	100	11½
1.108	24	86	44	100	25½	1.208	24	72	32	86	13	1.308	24	72	40	100	11
1.110	24	72	32	86	26½	1.210	28	72	32	100	13½	1.310	24	64	28	72	26
1.112	24	72	40	100	33½	1.212	28	72	32	100	13	1.312	40	64	24	100	29
1.114	24	64	32	86	37	1.214	24	86	48	100	25	1.314	28	86	44	100	23½
1.116	24	56	24	86	21	1.216	32	56	24	100	27½	1.316	28	64	32	100	20
1.118	28	72	32	100	26	1.218	24	72	40	100	24	1.318	24	86	48	100	10½
1.120	24	56	24	86	20½	1.220	28	86	40	100	20½	1.320	24	86	48	100	10
1.122	24	86	44	100	24	1.222	24	72	40	100	23½	1.322	28	72	32	86	24
1.124	24	56	24	86	20	1.224	28	86	40	100	20	1.324	32	56	24	100	15
1.126	24	86	44	100	23½	1.226	24	72	48	100	40	1.326	32	86	40	100	27
1.128	24	64	32	100	20	1.228	28	86	44	100	31	1.328	28	64	32	100	18½
1.130	24	72	40	100	32	1.230	28	64	32	100	28½	1.330	32	56	24	100	14
1.132	24	64	28	86	22	1.232	24	72	40	100	22½	1.332	28	64	32	100	18
1.134	24	56	24	86	18½	1.234	24	86	48	100	23	1.334	24	64	32	86	17
1.136	24	64	28	86	21½	1.236	24	72	40	100	22	1.336	32	56	24	100	13
1.138	24	64	32	100	18½	1.238	28	86	40	100	18	1.338	32	56	24	100	12½
1.140	24	64	28	86	21	1.240	24	72	40	100	21½	1.340	24	72	44	100	24
1.142	24	64	32	86	35	1.242	28	86	40	100	17½	1.342	28	64	32	100	16½
1.144	24	56	24	86	17	1.244	24	72	40	100	21	1.344	24	64	32	86	15½
1.146	24	86	44	100	21	1.246	32	72	40	100	45½	1.346	32	56	24	100	11
1.148	24	64	32	100	17	1.248	28	86	40	100	16½	1.348	32	56	24	100	10½

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
1.350	32	56	24	100	10
1.352	28	64	32	100	15
1.354	24	64	32	86	14
1.356	24	64	32	86	13½
1.358	28	64	32	100	14
1.360	28	72	32	86	20
1.362	24	64	32	86	12½
1.364	24	64	32	86	12
1.366	24	64	28	72	20½
1.368	28	72	32	86	19
1.370	28	86	44	100	17
1.372	24	64	32	86	10½
1.374	24	64	32	86	10
1.376	28	72	32	86	18
1.378	28	86	44	100	16
1.380	28	72	32	86	17½
1.382	24	64	32	72	34
1.384	28	86	44	100	15
1.386	40	64	24	100	22½
1.388	28	64	32	86	31½
1.390	28	86	44	100	14
1.392	44	64	24	100	32½
1.394	28	72	32	86	15½
1.396	28	86	44	100	13
1.398	28	72	32	86	15
1.400	40	64	24	100	21
1.402	28	86	44	100	12
1.404	28	72	32	86	14
1.406	28	86	44	100	11
1.408	24	64	28	72	15
1.410	28	72	32	86	13
1.412	24	64	28	72	14½
1.414	24	72	44	100	15½
1.416	24	64	44	86	42½
1.418	28	72	32	86	11½
1.420	28	72	32	86	11
1.422	40	64	24	100	18½
1.424	28	64	32	86	29
1.426	24	64	28	72	12
1.428	28	86	48	100	24
1.430	32	86	40	100	16
1.432	24	72	44	100	12½
1.434	24	64	28	72	10½
1.436	24	64	28	72	10
1.438	24	72	44	100	11½
1.440	24	72	44	100	11
1.442	24	72	44	100	10½
1.444	32	86	40	100	14
1.446	24	72	44	86	32
1.448	28	72	40	100	21½
1.450	32	86	40	100	13
1.452	40	64	24	100	14½
1.454	28	86	48	100	21½
1.456	24	72	40	86	20
1.458	32	86	40	100	11½
1.460	24	44	32	86	44
1.462	40	64	24	100	13
1.464	40	64	24	100	12½
1.466	24	72	40	86	19
1.468	28	64	40	100	33
1.470	40	64	24	100	11½
1.472	40	64	24	100	11
1.474	24	72	40	86	18
1.476	28	72	40	100	18½
1.478	24	72	40	86	17½
1.480	28	72	40	100	18
1.482	24	72	40	86	17
1.484	28	72	40	100	17½
1.486	24	72	40	86	16½
1.488	28	72	40	100	17
1.490	24	72	40	86	16
1.492	28	72	40	100	16½
1.494	24	72	40	86	15½
1.496	28	72	40	100	16
1.498	32	64	40	100	41½
1.500	28	64	40	100	31
1.502	28	86	48	100	16
1.504	24	72	40	86	14
1.506	28	72	40	100	14½
1.508	24	72	48	100	10½
1.510	24	72	40	86	13
1.512	24	64	44	86	38
1.514	24	72	48	86	35½
1.516	24	72	40	86	12
1.518	32	86	44	100	22
1.520	28	86	48	100	13½
1.522	24	72	40	86	11
1.524	24	72	40	86	10½
1.526	24	72	40	86	10
1.528	32	86	44	100	21
1.530	28	72	40	100	10½
1.532	28	72	40	100	10
1.534	28	86	48	100	11
1.536	32	72	40	86	42
1.538	24	72	48	100	16
1.540	28	100	56	72	45
1.542	24	72	48	100	15½
1.544	28	64	32	86	16½
1.546	24	72	48	100	15
1.548	28	64	32	86	18
1.550	44	64	24	100	20
1.552	24	72	48	100	12
1.554	24	64	40	86	23
1.556	24	64	32	72	21
1.558	24	72	44	86	24
1.560	44	64	24	100	10
1.562	24	72	48	100	11
1.564	24	72	44	86	25
1.566	32	86	44	100	11
1.568	24	72	48	100	10
1.570	32	72	40	100	28
1.572	28	64	32	86	11
1.574	32	86	44	100	10
1.576	24	72	48	100	10
1.578	44	64	24	100	11
1.580	28	64	32	86	11
1.582	44	64	24	100	11
1.584	40	56	24	100	22
1.586	28	64	32	86	11
1.588	32	86	44	100	11
1.590	44	64	24	100	11
1.592	28	64	32	86	11
1.594	44	64	24	100	11
1.596	28	64	44	100	33
1.598	28	64	32	86	11
1.600	44	56	24	100	20
1.602	24	64	32	72	11
1.604	32	86	44	100	11
1.606	24	64	32	72	11
1.608	44	64	24	100	11
1.610	32	86	44	100	11
1.612	32	86	44	100	11
1.614	44	64	24	100	11
1.616	40	56	24	100	11
1.618	24	64	32	72	11
1.620	44	64	24	100	11
1.622	44	64	24	100	11
1.624	24	64	32	72	11
1.626	24	72	44	86	11
1.628	24	64	32	72	11
1.630	24	64	32	72	11
1.632	28	72	44	100	11
1.634	24	64	32	72	11
1.636	24	64	32	72	11
1.638	32	86	48	100	22
1.640	28	72	40	86	22
1.642	24	64	32	72	11
1.644	24	64	40	86	11
1.646	28	72	40	86	22
1.648	40	56	24	100	11

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
.650	28	64	40	100	19½
.652	40	56	24	100	15½
.654	24	72	44	86	14
.656	28	72	44	100	14½
.658	24	72	44	86	13½
.660	28	72	44	100	14
.662	32	86	48	100	21½
.664	28	72	44	100	13½
.666	28	64	32	72	31
.668	24	72	44	86	12
.670	28	72	44	100	12½
.672	24	64	40	86	16½
.674	24	72	44	86	11
.676	24	72	44	86	10½
.678	28	64	40	100	16½
.680	28	72	44	100	11
.682	28	72	44	100	10½
.684	32	86	48	100	19½
.686	28	64	40	100	15½
.688	40	56	24	100	10
.690	28	64	40	100	15
.692	24	64	40	86	14
.694	32	72	44	100	30
.696	24	64	40	86	13½
.698	28	64	40	100	14
.700	32	72	40	100	17
.702	28	64	40	100	13½
.704	28	64	40	72	45½
.706	24	64	40	86	12
.708	28	64	40	100	12½
.710	28	72	40	86	19
.712	24	64	40	86	11
.714	32	64	40	100	31
.716	28	72	40	86	18½
.718	24	64	40	86	10
.720	28	72	40	86	18
.722	24	44	32	86	32
.724	28	100	56	86	19
.726	24	56	40	86	30
.728	32	72	40	100	13½
.730	28	72	40	86	17
.732	32	72	40	100	13
.734	28	72	40	86	16½
.736	32	72	40	100	12½
.738	32	56	40	100	40½
.740	32	86	48	100	13
.742	32	72	40	100	11½
.744	32	86	48	100	12½
.746	24	64	44	86	24½
.748	32	72	40	100	10½
1.750	32	86	48	100	11½
1.752	28	100	56	86	16
1.754	28	72	48	100	20
1.756	32	86	48	100	10½
1.758	32	72	44	100	26
1.760	28	72	48	100	19½
1.762	28	64	32	72	25
1.764	24	72	48	86	18½
1.766	28	72	40	86	12½
1.768	32	72	48	100	34
1.770	28	72	48	100	18½
1.772	44	56	24	100	20
1.774	24	72	48	86	17½
1.776	28	72	40	86	11
1.778	44	56	24	100	10½
1.780	28	100	56	86	12½
1.782	32	64	40	100	27
1.784	24	56	40	86	26½
1.786	28	100	56	86	11½
1.788	24	72	48	86	16
1.790	28	100	56	86	11
1.792	28	100	56	86	10½
1.794	44	56	24	100	18
1.796	28	64	32	72	22½
1.798	28	64	44	86	20½
1.800	32	72	44	100	23
1.802	28	64	32	72	22
1.804	32	72	44	86	37½
1.806	24	56	40	86	25
1.808	28	72	48	100	14½
1.810	28	72	48	86	33½
1.812	24	72	48	86	13
1.814	24	64	44	86	19
1.816	24	72	48	86	12½
1.818	28	72	44	86	24
1.820	24	64	44	86	18½
1.822	44	56	24	100	15
1.824	40	86	44	100	27
1.826	24	72	48	86	11
1.828	24	56	40	86	23½
1.830	28	72	48	100	11½
1.832	24	72	48	86	10
1.834	44	56	24	100	13½
1.836	28	72	48	100	10½
1.838	44	56	24	100	13
1.840	24	64	44	86	16½
1.842	32	72	40	86	27
1.844	28	64	32	72	18½
1.846	28	64	44	100	16½
1.848	44	56	24	100	11½
1.850	28	64	44	100	16
1.852	28	72	44	86	21½
1.854	44	56	24	100	10½
1.856	24	64	40	72	27
1.858	24	64	44	86	14½
1.860	32	72	44	100	18
1.862	24	64	44	86	14
1.864	28	64	44	100	14½
1.866	24	64	44	86	13½
1.868	28	64	44	100	14
1.870	24	64	44	86	13
1.872	28	64	44	100	13½
1.874	24	64	44	86	12½
1.876	28	64	44	100	13
1.878	28	64	32	72	15
1.880	24	64	44	86	11½
1.882	28	64	32	72	14½
1.884	24	64	44	86	11
1.886	28	64	44	100	11½
1.888	28	72	44	86	18½
1.890	24	64	44	86	10
1.892	32	72	48	100	27½
1.894	28	64	32	72	13
1.896	28	64	44	100	10
1.898	28	64	32	72	12½
1.900	28	64	40	86	21
1.902	28	64	32	72	12
1.904	24	64	48	86	24½
1.906	32	72	44	100	13
1.908	28	64	32	72	11
1.910	32	72	44	100	12½
1.912	28	64	32	72	10½
1.914	28	64	32	72	10
1.916	24	56	40	86	16
1.918	28	72	44	86	15½
1.920	32	72	44	100	11
1.922	28	72	44	86	15
1.924	28	64	40	86	19
1.926	32	72	44	100	10
1.928	28	64	44	86	30½
1.930	24	56	40	86	14½
1.932	32	64	40	100	15
1.934	24	56	40	86	14
1.936	32	64	40	100	14½
1.938	24	56	40	86	13½
1.940	28	64	48	100	22½
1.942	24	56	40	86	13
1.944	32	56	40	86	43
1.946	28	72	44	86	12
1.948	32	72	40	86	19½

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
1.950	28	72	44	86	11 4/5
1.952	40	86	44	100	17 1/2
1.954	24	64	48	86	21
1.956	32	72	48	100	23 3/4
1.958	40	86	44	100	17
1.960	28	72	44	86	10
1.962	48	56	24	100	17 1/2
1.964	24	64	40	72	19
1.966	28	64	40	86	15
1.968	40	86	44	100	16
1.970	32	64	40	100	10
1.972	48	56	24	100	16 1/2
1.974	24	44	32	86	13 1/2
1.976	28	64	44	86	28
1.978	24	44	32	86	13
1.980	28	64	48	100	19 1/4
1.982	24	44	32	86	12 3/4
1.984	28	48	40	86	43
1.986	24	44	32	86	12
1.988	28	56	32	72	26 1/2
1.990	28	64	40	86	12
1.992	48	56	24	100	14 1/4
1.994	28	64	40	86	11 1/2
1.996	24	44	32	86	10 1/2
1.998	28	64	40	86	11
2.000	48	56	24	100	13 1/2
2.002	40	86	44	100	12
2.004	28	64	40	86	10
2.006	40	86	44	100	11 1/2
2.008	48	56	24	100	12 1/2
2.010	32	72	40	86	13 3/4
2.012	48	56	24	100	12
2.014	32	72	40	86	13
2.016	40	86	44	100	10
2.018	32	72	40	86	12 1/4
2.020	28	72	48	86	21 3/4
2.022	32	72	40	86	12
2.024	28	64	48	100	15 1/4
2.026	48	56	24	100	10
2.028	28	64	48	100	15
2.030	24	64	40	72	13
2.032	32	72	40	86	10 1/2
2.034	24	64	40	72	12 1/2
2.036	32	72	40	86	10
2.038	28	64	48	100	14
2.040	32	72	48	100	17
2.042	28	64	48	100	13 1/2
2.044	40	44	24	100	20 3/4
2.046	28	64	48	100	13
2.048	24	64	40	72	10 1/2
2.050	28	64	48	100	12
2.052	28	64	44	86	23 1/2
2.054	28	64	48	100	12
2.056	40	86	48	100	23
2.058	24	64	48	86	10 3/4
2.060	32	72	48	100	15
2.062	24	56	40	72	30
2.064	44	48	28	100	36 1/2
2.066	32	56	40	86	39
2.068	28	64	48	100	10
2.070	32	72	48	100	14
2.072	32	56	40	100	25
2.074	32	72	48	100	13 1/2
2.076	28	72	48	86	17
2.078	32	72	48	100	13
2.080	32	64	44	100	19
2.082	32	72	48	100	12 1/2
2.084	28	64	40	72	31
2.086	32	72	48	100	12
2.088	28	100	56	72	16 1/2
2.090	32	72	48	100	11 1/2
2.092	28	72	48	86	15 1/2
2.094	32	72	48	100	11
2.096	28	64	44	86	20 1/2
2.098	32	64	44	100	17 1/2
2.100	28	44	32	86	27
2.102	28	72	48	86	14 3/4
2.104	28	100	56	72	15
2.106	28	72	48	86	14
2.108	40	44	24	100	15
2.110	28	64	44	86	19 3/4
2.112	40	44	24	100	14 3/4
2.114	28	56	32	72	18
2.116	28	64	44	86	19
2.118	28	100	56	72	13 1/2
2.120	28	72	48	86	12 3/4
2.122	28	100	56	72	13
2.124	28	72	48	86	12
2.126	28	100	56	72	12 1/2
2.128	28	64	44	86	18
2.130	28	100	56	72	12
2.132	24	64	44	72	21 1/2
2.134	28	100	56	72	11 1/2
2.136	28	56	32	72	16
2.138	28	72	48	86	10
2.140	24	56	40	72	26
2.142	28	100	56	72	10 1/2
2.144	40	72	48	100	36 1/2
2.146	28	56	32	72	15
2.148	44	86	48	100	29
2.150	32	72	44	86	19
2.152	32	64	44	100	12
2.154	24	64	44	72	20
2.156	32	64	44	100	11 1/2
2.158	24	56	40	72	25
2.160	32	64	44	100	11
2.162	40	86	48	100	14 1/2
2.164	32	64	40	86	21 1/2
2.166	32	64	48	100	25 1/2
2.168	32	56	40	100	18 1/2
2.170	32	72	48	86	29
2.172	28	64	44	86	14
2.174	32	56	40	100	18
2.176	56	64	32	100	39
2.178	40	72	44	100	27
2.180	40	86	48	100	12 1/2
2.182	28	72	56	86	30 1/2
2.184	24	56	44	72	33 1/2
2.186	32	72	44	86	16
2.188	28	56	32	72	10
2.190	32	56	40	86	34 1/2
2.192	40	86	48	100	11
2.194	28	64	40	72	25 1/2
2.196	40	86	48	100	10 1/2
2.198	44	86	48	100	26 1/2
2.200	24	56	40	72	22 1/2
2.202	32	72	44	86	14 1/2
2.204	28	64	44	86	10
2.206	32	72	44	86	14
2.208	32	56	40	100	15
2.210	48	100	56	86	45
2.212	32	64	40	86	18
2.214	24	64	44	72	15
2.216	32	72	44	86	13
2.218	32	56	40	100	14
2.220	32	72	44	86	12 1/4
2.222	28	64	48	86	24 1/4
2.224	32	72	44	86	12
2.226	44	86	48	100	25
2.228	32	72	44	86	11 1/4
2.230	32	64	40	86	16 1/2
2.232	32	72	44	86	11
2.234	44	48	28	100	29 1/2
2.236	32	72	44	86	10 1/2
2.238	24	64	44	72	12 3/4
2.240	32	56	40	100	11 1/4
2.242	24	64	44	72	12
2.244	32	56	40	100	11
2.246	24	64	44	72	11 1/4
2.248	32	56	40	100	10

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
2.250	24	64	44	72	11
2.255	32	64	48	100	20
2.260	44	56	32	100	26
2.265	28	44	32	86	17
2.270	28	44	32	86	16½
2.275	32	64	40	86	12
2.280	28	64	44	72	31½
2.285	44	86	48	100	21½
2.290	24	44	40	86	25½
2.295	32	64	48	100	17
2.300	24	56	40	72	15
2.305	24	56	40	72	14½
2.310	24	56	40	72	14
2.315	24	56	40	72	13½
2.320	28	44	32	86	11½
2.325	28	44	32	86	11
2.330	40	100	56	72	41½
2.335	28	64	48	86	17
2.340	24	56	48	72	35
2.345	24	56	40	72	10
2.350	28	64	44	72	28½
2.355	44	86	48	100	16½
2.360	32	64	48	100	10½
2.365	24	56	48	86	8½
2.370	44	56	32	100	10½
2.375	28	64	48	86	13½
2.380	32	100	56	72	17
2.385	32	72	56	86	34½
2.390	28	64	40	72	10½
2.395	40	72	44	100	11½
2.400	56	64	32	100	31
2.405	28	64	48	86	10
2.410	32	100	56	72	14½
2.415	44	86	48	100	10½
2.420	32	100	56	72	13½
2.425	32	100	56	72	13
2.430	32	100	56	72	12½
2.435	32	72	48	86	11
2.440	32	72	48	86	10½
2.445	44	56	32	100	13½
2.450	24	64	48	72	11½
2.455	40	72	48	100	23
2.460	28	64	48	72	32½
2.465	32	64	44	86	15½
2.470	28	40	32	86	18½
2.475	32	64	40	72	27
2.480	44	48	28	100	15
2.485	28	72	56	86	11
2.490	28	72	56	86	10½
2.495	24	44	40	86	10½
2.500	28	64	48	72	31
2.505	24	56	44	72	17
2.510	28	40	44	86	45½
2.515	32	64	44	86	10½
2.520	44	48	28	100	11
2.525	48	56	32	100	23
2.530	24	56	44	72	15
2.535	32	56	40	86	17½
2.540	32	64	48	86	24½
2.545	32	56	44	86	20½
2.550	28	64	44	72	17½
2.555	32	56	40	86	16
2.560	32	64	48	86	23½
2.565	28	40	32	86	10
2.570	44	48	40	100	45½
2.575	24	56	44	72	10½
2.580	40	72	56	86	44½
2.585	32	56	40	86	13½
2.590	32	56	40	86	13
2.595	44	40	32	100	42½
2.600	32	56	40	86	12
2.605	32	56	40	86	11½
2.610	32	64	40	72	20
2.615	44	48	40	100	44½
2.620	28	64	44	72	11½
2.625	44	56	24	64	27
2.630	48	56	32	100	16½
2.635	40	72	44	86	22
2.640	48	100	56	72	45
2.645	24	40	44	86	30½
2.650	40	56	44	86	43½
2.655	56	64	32	100	18½
2.660	44	48	40	100	43½
2.665	28	64	48	72	24
2.670	28	48	44	72	41½
2.675	48	64	28	56	44½
2.680	28	44	48	86	41
2.685	48	100	56	72	44
2.690	40	64	44	100	12
2.695	40	64	44	100	11½
2.700	28	44	48	86	40½
2.705	56	64	32	100	15
2.710	40	72	56	86	41½
2.715	40	56	44	86	42
2.720	48	64	28	56	43½
2.725	44	48	40	100	42
2.730	48	100	56	72	43
2.735	44	40	32	100	39
2.740	28	44	48	86	39½
2.745	40	72	44	86	15
2.750	28	64	48	72	10½
2.755	44	40	32	100	38½
2.760	28	44	48	86	39
2.765	48	64	28	56	42½
2.770	28	48	44	72	39
2.775	40	72	44	86	12½
2.780	40	72	44	86	12
2.785	24	44	48	72	40
2.790	28	48	44	72	38½
2.795	32	48	40	72	41
2.800	24	56	48	72	11
2.805	24	56	48	72	11
2.810	44	56	24	64	17½
2.815	28	44	40	86	18
2.820	40	56	44	86	39½
2.825	32	56	44	72	36
2.830	48	64	28	56	41
2.835	28	48	40	72	29
2.840	40	56	44	86	39
2.845	28	44	40	86	16
2.850	28	56	64	86	40
2.855	28	44	48	86	36½
2.860	40	56	44	86	38½
2.865	24	44	48	72	38
2.870	44	48	40	100	38½
2.875	40	64	48	86	34½
2.880	48	100	56	72	39½
2.885	24	44	48	72	37½
2.890	44	48	40	100	38
2.895	32	56	44	72	34
2.900	28	44	40	86	11½
2.905	40	72	48	86	20½
2.910	28	44	40	86	10½
2.915	28	40	44	86	35½
2.920	28	48	44	72	35
2.925	40	64	48	86	33
2.930	32	64	44	72	16½
2.935	48	64	28	56	38½
2.940	40	64	48	100	11½
2.945	40	72	56	86	35½
2.950	40	64	48	100	10½
2.955	48	64	28	56	38
2.960	24	44	48	72	35½
2.965	32	64	44	72	14
2.970	32	64	48	72	27
2.975	40	56	44	86	35½
2.980	48	40	28	100	27½
2.985	44	48	40	100	35½
2.990	28	48	44	72	33
2.995	48	64	28	56	37

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
3.000	40	100	56	64	31
3.005	40	64	48	86	30½
3.010	28	56	64	86	36
3.015	48	64	28	50	36½
3.020	48	100	56	72	36
3.025	40	100	56	72	13½
3.030	40	64	44	72	37½
3.035	24	40	48	86	25
3.040	44	48	40	100	34
3.045	32	64	48	72	24
3.050	40	56	44	100	14
3.055	56	44	28	86	42½
3.060	28	44	48	86	30½
3.065	40	56	44	86	33
3.070	28	40	44	86	31
3.075	44	48	40	100	33
3.080	40	64	48	86	28
3.085	28	56	64	86	34
3.090	48	64	28	56	34½
3.095	48	100	56	72	34
3.100	24	44	48	72	31½
3.105	40	100	56	64	27½
3.110	44	48	40	100	32
3.115	28	48	40	72	16
3.120	44	64	48	100	19
3.125	32	56	44	72	26½
3.130	32	56	48	86	11
3.135	28	44	48	86	28
3.140	32	56	48	86	10
3.145	48	64	28	56	33
3.150	28	44	48	86	27½
3.155	28	64	56	72	22
3.160	44	48	40	100	30½
3.165	24	44	48	72	29
3.170	28	48	40	72	12
3.175	32	48	40	72	31
3.180	40	56	44	86	29½
3.185	40	100	56	64	24½
3.190	28	56	64	86	31
3.195	44	72	48	86	20½
3.200	48	100	56	72	31
3.205	28	40	44	86	26½
3.210	24	44	48	72	28
3.215	40	64	48	72	39½
3.220	56	44	28	86	39
3.225	24	44	48	72	27½
3.230	48	40	28	100	16
3.235	32	72	64	86	12
3.240	24	44	48	72	27
3.245	28	40	44	86	25
3.250	44	64	48	100	10
3.255	32	48	40	72	28½
3.260	32	56	44	72	21
3.265	48	100	56	72	29
3.270	40	56	44	86	26½
3.275	44	40	32	100	21½
3.280	48	64	28	56	29
3.285	32	48	40	72	27½
3.290	32	44	40	86	13½
3.295	24	44	48	72	25
3.300	32	48	40	72	27
3.305	40	72	56	86	24
3.310	44	48	40	100	25½
3.315	32	48	40	72	26½
3.320	28	40	44	86	22
3.325	40	56	44	86	24½
3.330	28	56	64	86	26½
3.335	28	64	56	72	11½
3.340	40	64	44	72	29
3.345	32	44	48	86	34½
3.350	44	48	40	100	24
3.355	48	100	56	72	26
3.360	40	56	48	100	11½
3.365	28	40	44	86	20
3.370	48	64	28	56	26
3.375	44	48	40	100	23
3.380	32	56	48	72	27½
3.385	48	64	28	56	25½
3.390	48	40	32	100	28
3.395	32	56	44	72	13½
3.400	40	56	44	86	21½
3.405	28	44	48	86	16½
3.410	32	48	40	72	23
3.415	28	40	44	86	17½
3.420	32	40	48	86	40
3.425	28	56	64	86	23
3.430	28	44	48	86	15
3.435	44	48	40	100	20½
3.440	48	100	56	64	35
3.445	28	44	48	86	14
3.450	28	56	64	86	22
3.455	40	56	44	86	19
3.460	40	72	56	86	17
3.465	32	64	56	72	27
3.470	28	48	56	86	24
3.475	40	56	44	86	18
3.480	28	48	44	72	12
3.485	40	56	44	86	17
3.490	32	40	44	86	31
3.495	24	44	48	72	16
3.500	28	48	44	72	11
3.505	28	48	44	72	10½
3.510	40	72	56	86	14
3.515	28	40	44	86	11
3.520	24	44	48	72	14½
3.525	44	48	40	100	16
3.530	40	56	44	86	15
3.535	24	44	48	72	13½
3.540	48	100	56	72	18½
3.545	40	56	44	86	14
3.550	24	44	48	72	12½
3.555	40	56	48	100	19½
3.560	40	56	44	86	13
3.565	40	64	44	72	21
3.570	48	100	56	72	17
3.575	24	44	48	72	10½
3.580	44	48	40	100	12½
3.585	48	40	32	100	21
3.590	40	64	48	72	30½
3.595	56	40	28	100	23½
3.600	44	48	40	100	11
3.605	48	64	28	56	16
3.610	28	56	64	86	14
3.615	32	44	40	72	26½
3.620	48	40	32	100	19½
3.625	44	56	48	100	16
3.630	32	48	40	72	11½
3.635	28	40	48	86	21½
3.640	28	56	64	86	12
3.645	48	100	56	72	12½
3.650	40	72	64	86	28
3.655	32	64	56	72	20
3.660	28	48	56	86	15½
3.665	48	100	56	72	11
3.670	48	100	56	72	10½
3.675	48	64	28	56	11½
3.680	32	56	48	72	15
3.685	28	48	56	86	14
3.690	56	48	24	64	32½
3.695	44	56	48	100	11½
3.700	48	40	32	100	15½
3.705	32	56	48	72	13½
3.710	44	100	56	64	15½
3.715	28	48	56	86	12
3.720	32	56	48	72	12½
3.725	56	44	28	86	26
3.730	48	64	32	56	29½
3.735	40	64	44	72	12
3.740	56	44	28	86	25½
3.745	40	64	48	72	26

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
3.750	32	44	48	86	22½
3.755	40	64	44	72	10½
3.760	44	64	48	86	11½
3.765	32	64	56	72	14½
3.770	48	40	32	100	11
3.775	48	100	56	64	26
3.780	40	56	48	86	18½
3.785	40	48	44	72	42
3.790	32	48	44	72	21½
3.795	56	40	28	100	14½
3.800	56	44	28	86	23½
3.805	44	72	56	86	17
3.810	56	40	32	86	43
3.815	56	44	28	86	23
3.820	56	40	28	100	13
3.825	44	72	56	86	16
3.830	40	64	56	72	38
3.835	28	40	48	86	11
3.840	32	48	44	72	19½
3.845	28	44	48	72	25
3.850	40	64	48	72	22½
3.855	56	40	28	100	10½
3.860	56	40	28	100	10
3.865	56	40	28	86	32
3.870	32	40	44	86	19
3.875	32	48	44	72	18
3.880	32	44	56	86	35
3.885	44	72	56	86	12½
3.890	40	64	48	72	21
3.895	40	48	44	86	24
3.900	56	44	28	72	38
3.905	28	44	48	72	23
3.910	56	48	28	64	40
3.915	48	64	32	56	24
3.920	32	44	40	72	14
3.925	40	56	48	86	10
3.930	56	44	28	86	18½
3.935	32	48	44	72	15
3.940	40	64	48	72	19
3.945	48	64	32	56	23
3.950	48	72	56	86	24½
3.955	32	44	48	86	13
3.960	28	44	48	72	21
3.965	56	48	24	64	25
3.970	32	44	48	86	12
3.975	32	56	64	72	38½
3.980	32	40	44	86	13½
3.985	40	64	48	72	17
3.990	44	56	48	86	24½
3.995	40	64	48	72	16½

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
4.000	28	40	48	72	31
4.005	40	64	48	72	16
4.010	56	40	32	100	26½
4.015	40	64	48	72	15½
4.020	40	72	64	86	13½
4.025	40	64	48	72	15
4.030	32	40	48	86	25½
4.035	44	64	56	72	41
4.040	48	64	32	56	10½
4.045	56	48	44	100	38
4.050	40	72	64	86	11½
4.055	40	48	44	86	18
4.060	40	64	48	72	13
4.065	44	64	48	72	27½
4.070	44	72	64	86	20½
4.075	56	44	28	86	10½
4.080	44	56	48	86	21½
4.085	56	48	24	64	21
4.090	40	64	48	72	11
4.095	28	48	56	72	25½
4.100	48	100	56	64	12½
4.105	44	72	64	86	25½
4.110	48	64	32	56	10½
4.115	40	56	44	72	19½
4.120	48	64	32	56	16
4.125	28	44	48	72	13½
4.130	48	100	56	64	10½
4.135	32	56	64	86	13½
4.140	28	40	48	72	27½
4.145	28	48	56	72	24
4.150	48	64	32	56	14½
4.155	44	72	64	86	24
4.160	56	40	32	86	37
4.165	44	64	56	86	21½
4.170	44	64	48	72	24½
4.175	56	44	24	64	29
4.180	56	40	28	86	23½
4.185	40	56	44	72	16½
4.190	64	48	32	72	45
4.195	28	40	48	72	26
4.200	48	64	32	56	11½
4.205	48	44	40	100	15½
4.210	56	40	32	100	20
4.215	48	44	40	100	15
4.220	32	44	56	86	27
4.225	48	44	40	100	14½
4.230	28	40	48	72	25
4.235	40	56	44	72	14
4.240	32	44	48	72	29
4.245	56	48	24	64	14

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
4.250	28	48	56	72	20½
4.255	56	40	28	86	21
4.260	44	72	64	86	20½
4.265	56	44	28	64	40
4.270	44	64	56	86	17½
4.275	32	44	56	86	25½
4.280	28	40	48	72	23½
4.285	40	56	44	72	11
4.290	28	48	56	72	19
4.295	56	48	24	64	11
4.300	44	72	64	86	19
4.305	44	56	48	86	11
4.310	32	44	56	86	24½
4.315	28	48	56	72	18
4.320	44	64	48	72	19½
4.325	44	72	64	86	18
4.330	28	56	64	72	13
4.335	56	40	28	86	18
4.340	72	48	24	64	39½
4.345	64	48	24	56	40½
4.350	28	48	56	72	16½
4.355	28	56	64	72	11½
4.360	32	44	56	86	23
4.365	56	40	32	100	13
4.370	56	40	28	86	16½
4.375	32	44	56	86	22½
4.380	48	72	64	86	28
4.385	40	48	64	86	45
4.390	56	40	32	100	11½
4.395	44	64	56	86	11
4.400	40	56	48	72	22½
4.405	44	64	48	72	16
4.410	56	44	24	64	22½
4.415	40	56	48	72	22
4.420	48	72	64	86	27
4.425	64	40	32	86	42
4.430	28	48	56	72	12½
4.435	48	64	56	72	40½
4.440	44	72	64	86	12½
4.445	56	48	44	100	30
4.450	32	44	56	86	23
4.455	86	56	24	72	29½
4.460	40	56	48	72	20½
4.465	44	64	48	72	13
4.470	44	48	56	86	41½
4.475	28	40	48	72	16½
4.480	40	44	48	86	28
4.485	56	44	28	72	25
4.490	32	48	56	72	30
4.495	32	44	48	72	22

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle	Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle	Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
4.500	56	44	32	64	45	4.750	32	44	48	72	11½	5.000	48	64	56	72	31
4.505	56	44	28	64	36	4.755	64	40	32	86	37	5.005	56	44	28	64	26
4.510	44	64	56	72	32½	4.760	44	56	64	86	35½	5.010	56	48	28	64	11
4.515	48	64	44	56	40	4.765	64	48	24	56	33½	5.015	40	48	44	72	10
4.520	86	56	24	72	28	4.770	86	48	24	72	37	5.020	40	44	56	86	32
4.525	40	48	56	86	33½	4.775	40	56	24	64	34	5.025	64	48	32	72	32
4.530	56	72	64	86	38½	4.780	40	64	56	72	10½	5.030	56	48	44	100	11½
4.535	40	44	56	86	40	4.785	44	56	48	72	24	5.035	44	56	48	72	16
4.540	64	48	32	72	40	4.790	44	56	64	86	35	5.040	32	44	56	72	27
4.545	72	56	24	64	10½	4.795	86	56	24	72	20½	5.045	64	48	24	56	28
4.550	48	72	64	86	23½	4.800	64	44	32	86	27½	5.050	48	64	40	56	10½
4.555	56	44	28	72	23	4.805	44	40	48	86	38½	5.055	56	48	44	100	10
4.560	48	64	56	86	21	4.810	48	64	56	86	10	5.060	86	64	28	72	14½
4.565	28	40	48	72	12	4.815	32	40	44	72	10	5.065	86	48	24	72	32
4.570	32	44	48	72	10½	4.820	40	44	56	86	35½	5.070	40	56	64	86	17½
4.575	32	44	56	86	15	4.825	64	48	32	72	35½	5.075	40	44	56	86	31
4.580	48	64	44	56	39	4.830	86	56	24	64	33	5.080	64	48	32	72	31
4.585	32	44	56	86	14½	4.835	48	64	40	56	25½	5.085	86	56	24	64	28
4.590	48	64	56	86	20	4.840	56	48	28	64	18½	5.090	32	48	56	72	11
4.595	32	44	56	86	14	4.845	32	56	64	72	17½	5.095	56	40	32	86	12
4.600	40	56	48	72	15	4.850	56	44	28	72	11½	5.100	32	40	48	72	17
4.605	32	44	56	86	13½	4.855	86	56	24	72	18½	5.105	40	44	64	86	41
4.610	40	56	48	72	14½	4.860	44	48	56	86	35½	5.110	56	72	64	86	28
4.615	32	44	56	86	13	4.865	40	44	48	86	10½	5.115	40	48	56	86	10½
4.620	40	56	48	72	14	4.870	48	72	64	86	11	5.120	44	40	48	86	33½
4.625	44	56	48	72	28	4.875	40	56	64	86	23½	5.125	56	44	28	64	23
4.630	86	56	24	64	36½	4.880	86	44	24	72	41½	5.130	64	40	32	86	30½
4.635	40	44	48	86	24	4.885	48	64	44	56	34	5.135	40	56	64	86	15
4.640	40	56	48	72	13	4.890	44	48	56	86	35	5.140	44	44	48	72	32
4.645	48	64	56	86	18	4.895	32	56	64	72	15½	5.145	40	48	56	86	18½
4.650	32	40	44	72	18	4.900	72	44	24	64	37	5.150	48	64	56	72	28
4.655	56	44	32	64	43	4.905	64	44	32	86	25	5.155	86	40	24	72	44
4.660	64	40	32	86	38½	4.910	86	56	24	64	31½	5.160	40	48	56	86	18
4.665	40	44	56	86	38	4.915	72	48	28	64	41½	5.165	44	64	56	72	15
4.670	64	48	32	72	38	4.920	48	64	56	72	32½	5.170	72	44	24	56	42½
4.675	48	64	44	56	37½	4.925	56	40	32	86	19	5.175	32	40	48	72	14
4.680	64	48	24	56	35	4.930	56	48	28	64	15	5.180	56	72	64	86	26½
4.685	56	44	24	64	11	4.935	56	72	64	86	31½	5.185	56	40	48	100	30½
4.690	32	44	56	72	34	4.940	32	56	64	72	13½	5.190	40	56	64	86	12½
4.695	40	64	56	72	15	4.945	86	56	24	72	15	5.195	44	48	56	86	29½
4.700	44	56	64	86	36½	4.950	32	56	64	72	13	5.200	64	48	24	56	24½
4.705	48	72	64	86	18½	4.955	56	40	28	64	36	5.205	64	32	28	72	48
4.710	32	56	64	72	22	4.960	32	56	64	72	12½	5.210	44	56	64	86	27
4.715	56	48	28	64	22½	4.965	64	40	32	86	33½	5.215	72	48	24	64	22
4.720	56	44	28	72	17½	4.970	64	48	32	72	33	5.220	48	64	56	72	26½
4.725	56	48	44	100	23	4.975	44	64	56	72	21½	5.225	48	56	64	86	35
4.730	44	56	64	86	36	4.980	86	48	24	72	33½	5.230	44	64	56	72	12
4.735	44	48	56	86	37½	4.985	44	56	64	86	31½	5.235	40	56	64	86	10
4.740	72	56	24	64	10½	4.990	72	48	24	64	27½	5.240	86	56	24	64	24½
4.745	56	44	28	72	16½	4.995	32	44	56	72	28	5.245	32	44	56	72	22

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
5.250	56	40	28	64	31
5.255	44	56	64	86	26
5.260	64	48	24	56	23
5.265	48	64	56	72	25½
5.270	44	48	56	86	28
5.275	40	44	56	86	27
5.280	64	48	32	72	27
5.285	64	40	32	72	42
5.290	56	44	48	100	30
5.295	44	48	56	86	27½
5.300	40	44	48	72	29
5.305	64	40	32	86	27
5.310	56	44	28	64	17½
5.315	56	40	28	72	12½
5.320	44	56	64	86	24½
5.325	56	40	28	72	12
5.330	64	44	32	86	10
5.335	64	48	24	56	21
5.340	86	56	24	64	22
5.345	86	48	24	72	26½
5.350	72	48	24	64	18
5.355	40	56	64	72	32½
5.360	64	44	32	72	34
5.365	44	48	56	86	26
5.370	64	48	24	56	20
5.375	86	44	28	72	25
5.380	32	44	56	72	18
5.385	56	72	64	86	21½
5.390	86	48	24	72	25½
5.395	32	44	56	72	17½
5.400	56	32	28	72	37½
5.405	64	44	28	56	42
5.410	44	48	56	86	25
5.415	86	64	40	72	43½
5.420	72	48	24	64	15½
5.425	48	64	44	56	23
5.430	86	64	32	56	45
5.435	64	48	32	72	23½
5.440	44	56	64	86	21½
5.445	48	64	44	56	22½
5.450	64	48	24	56	17½
5.455	64	48	32	72	23
5.460	64	40	32	86	23½
5.465	44	56	64	72	38½
5.470	72	48	24	64	14½
5.475	64	48	32	72	22½
5.480	48	56	64	72	24
5.485	72	48	32	64	43
5.490	86	44	24	64	41½
5.495	44	48	56	86	23

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
5.500	64	32	28	72	45
5.505	56	72	64	86	18
5.510	72	56	32	64	31
5.515	44	48	56	86	22½
5.520	64	40	32	86	22
5.525	86	44	24	72	32
5.530	72	48	32	64	42½
5.535	56	72	64	86	17
5.540	64	40	32	86	21½
5.545	40	44	56	86	20
5.550	56	72	64	86	16½
5.555	48	64	44	56	19
5.560	48	44	56	86	38
5.565	64	40	32	72	38½
5.570	86	40	24	72	39
5.575	86	48	24	72	21
5.580	40	44	56	86	19½
5.585	86	44	24	72	31
5.590	40	48	64	72	41
5.595	56	40	28	64	24
5.600	86	56	24	64	13½
5.605	48	64	44	56	18
5.610	40	44	56	72	37½
5.615	86	44	24	64	40
5.620	64	48	32	72	18½
5.625	86	56	32	72	34
5.630	86	48	24	72	19½
5.635	48	64	44	56	17
5.640	56	72	64	86	13
5.645	44	40	56	86	38
5.650	48	64	44	56	16½
5.655	64	44	32	72	29
5.660	48	64	56	72	14
5.665	48	64	44	56	16
5.670	56	40	44	100	23
5.675	56	32	28	72	33½
5.680	86	48	24	72	18
5.685	44	56	64	86	13½
5.690	48	44	64	86	45
5.695	48	64	56	72	12
5.700	56	72	64	86	10
5.705	40	44	56	86	15½
5.710	64	48	32	72	15½
5.715	40	48	64	72	39½
5.720	40	44	56	72	36
5.725	86	44	24	72	28½
5.730	48	64	44	56	13
5.735	48	64	56	72	10½
5.740	44	56	64	86	11
5.745	72	48	32	64	40

Lead	Gear on Worm	1st Intermediate	2nd Intermediate	Gear on Screw	Angle
5.750	64	48	32	72	14
5.755	86	48	24	72	15½
5.760	86	64	40	72	39½
5.765	44	48	56	86	15
5.770	64	44	28	56	37½
5.775	48	64	44	56	11½
5.780	40	44	56	86	12½
5.785	64	48	32	72	12½
5.790	64	40	32	86	13½
5.795	86	48	24	72	14
5.800	64	44	24	56	21½
5.805	44	48	56	72	35½
5.810	86	48	28	72	33½
5.815	86	44	24	64	37½
5.820	64	44	24	56	21
5.825	64	40	32	72	35
5.830	86	48	24	72	12½
5.835	64	40	32	86	11½
5.840	44	48	56	72	35
5.845	64	40	32	86	11
5.850	86	56	32	72	31
5.855	48	44	56	86	34½
5.860	64	40	32	72	34½
5.865	64	40	28	72	19½
5.870	72	48	32	64	38½
5.875	56	40	44	100	17½
5.880	86	56	32	72	30½
5.885	72	44	28	56	44
5.890	44	56	64	72	32½
5.895	44	40	48	72	36½
5.900	56	64	40	48	36
5.905	40	44	48	72	13
5.910	72	48	32	64	38
5.915	40	48	64	72	37
5.920	40	48	56	72	24
5.925	86	64	32	56	39½
5.930	86	44	24	64	36
5.935	72	44	28	64	34
5.940	86	56	32	72	29½
5.945	44	40	48	86	14½
5.950	72	48	32	64	37½
5.955	44	56	64	72	31½
5.960	40	44	48	72	10½
5.965	40	48	56	72	23
5.970	44	40	48	72	35½
5.975	56	44	48	100	12
5.980	44	48	56	72	33
5.985	40	56	64	72	19½
5.990	72	48	32	64	37
5.995	44	48	64	86	28½

Gearing for Cutting Worm and Spiral Gears

Leads from 0.670 to 3.143 Inches

$$\frac{\text{Lead}}{10} = \frac{\text{Driven}}{\text{Drivers}} = \frac{\text{Second} \times \text{Worm}}{\text{First} \times \text{Screw}}$$

Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)	Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)	Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)
0.670	24	86	24	100	1.714	40	56	24	100	2.442	28	64	48	86
0.781	24	86	28	100	1.744	24	64	40	86	2.444	40	72	44	100
0.800	24	72	24	100	1.750	28	64	40	100	2.450	56	64	28	100
0.893	24	86	32	100	1.778	32	72	40	100	2.456	44	86	48	100
0.900	24	64	24	100	1.786	32	86	48	100	2.481	32	72	48	86
0.930	24	72	24	86	1.809	28	72	40	86	2.489	32	100	56	72
0.933	24	72	28	100	1.823	28	100	56	86	2.500	24	64	48	72
1.029	24	56	24	100	1.860	24	72	48	86	2.514	44	56	32	100
1.042	28	86	32	100	1.867	28	72	48	100	2.532	28	72	56	86
1.047	24	64	24	86	1.886	44	56	24	100	2.537	24	44	40	86
1.050	24	64	28	100	1.919	24	64	44	86	2.558	32	64	44	86
1.067	24	72	32	100	1.925	28	64	44	100	2.567	44	48	28	100
1.085	24	72	28	86	1.944	28	64	32	72	2.605	28	40	32	86
1.116	24	86	40	100	1.956	32	72	44	100	2.619	24	56	44	72
1.196	24	56	24	86	1.990	28	72	44	86	2.658	32	56	40	86
1.200	24	64	32	100	1.993	24	56	40	86	2.667	40	72	48	100
1.221	24	64	28	86	2.000	32	64	40	100	2.674	28	64	44	72
1.228	24	86	44	100	2.030	24	44	32	86	2.713	28	48	40	86
1.240	24	72	32	86	2.035	28	64	40	86	2.743	48	56	32	100
1.244	28	72	32	100	2.047	40	86	44	100	2.750	40	64	44	100
1.302	28	86	40	100	2.057	48	56	24	100	2.778	32	64	40	72
1.333	24	72	40	100	2.067	32	72	40	86	2.791	32	64	48	86
1.340	24	86	48	100	2.083	24	64	40	72	2.800	56	64	32	100
1.371	32	56	24	100	2.093	24	64	48	86	2.842	40	72	44	86
1.395	24	64	32	86	2.100	28	64	48	100	2.849	28	64	56	86
1.400	28	64	32	100	2.133	32	72	48	100	2.857	24	56	48	72
1.433	28	86	44	100	2.171	28	72	48	86	2.865	44	100	56	86
1.447	28	72	32	86	2.178	28	100	56	72	2.880	48	40	24	100
1.458	24	64	28	72	2.182	40	44	24	100	2.894	32	72	56	86
1.467	24	72	44	100	2.193	24	56	44	86	2.917	28	64	48	72
1.488	32	86	40	100	2.200	32	64	44	100	2.924	32	56	44	86
1.500	40	64	24	100	2.222	28	56	32	72	2.933	44	72	48	100
1.550	24	72	40	86	2.233	40	86	48	100	2.946	44	56	24	64
1.556	28	72	40	100	2.238	28	64	44	86	2.960	28	44	40	86
1.563	28	86	48	100	2.274	32	72	44	86	2.984	28	48	44	86
1.595	24	56	32	86	2.286	32	56	40	100	3.000	40	64	48	100
1.600	24	72	48	100	2.292	24	64	44	72	3.044	24	44	48	86
1.628	28	64	32	86	2.326	32	64	40	86	3.056	32	64	44	72
1.637	32	86	44	100	2.368	28	44	32	86	3.070	24	40	44	86
1.650	44	64	24	100	2.381	24	56	40	72	3.101	40	72	48	86
1.667	24	64	32	72	2.392	24	56	48	86	3.111	40	100	56	72
1.705	24	72	44	86	2.400	32	64	48	100	3.126	48	100	56	86
1.711	28	72	44	100	2.431	28	64	40	72	3.143	40	56	44	100

For leads up to 3.143 inches.

Gearing for Cutting Worm and Spiral Gears

Leads from 3.175 to 6.667 Inches

$$\frac{\text{Lead}}{10} = \frac{\text{Driven}}{\text{Drivers}} = \frac{\text{Second} \times \text{Worm}}{\text{First} \times \text{Screw}}$$

Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)	Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)	Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)
3.175	32	56	40	72	4.040	32	44	40	72	5.185	32	48	56	72
3.189	32	56	48	86	4.059	32	44	48	86	5.209	56	40	32	86
3.198	40	64	44	86	4.070	40	64	56	86	5.226	86	64	28	72
3.241	28	48	40	72	4.074	32	48	44	72	5.238	44	56	48	72
3.256	32	64	56	86	4.093	32	40	44	86	5.316	40	56	64	86
3.267	56	48	28	100	4.134	40	72	64	86	5.333	32	40	48	72
3.300	44	64	48	100	4.144	56	44	28	86	5.347	44	64	56	72
3.307	32	72	64	86	4.167	40	64	48	72	5.357	48	64	40	56
3.333	32	64	48	72	4.200	48	100	56	64	5.412	64	44	32	86
3.349	24	40	48	86	4.242	28	44	48	72	5.426	40	48	56	86
3.360	48	40	28	100	4.252	32	56	64	86	5.444	56	40	28	72
3.383	32	44	40	86	4.264	40	48	44	86	5.568	56	44	28	64
3.403	28	64	56	72	4.286	48	64	32	56	5.625	72	48	24	64
3.411	44	72	48	86	4.341	48	72	56	86	5.657	32	44	56	72
3.422	44	100	56	72	4.364	48	44	40	100	5.714	64	48	24	56
3.429	40	56	48	100	4.365	40	56	44	72	5.759	86	56	24	64
3.488	40	64	48	86	4.375	56	48	24	64	5.788	56	72	64	86
3.492	32	56	44	72	4.385	44	56	48	86	5.833	48	64	56	72
3.500	40	100	56	64	4.444	28	56	64	72	5.847	44	56	64	86
3.520	44	40	32	100	4.465	32	40	48	86	5.893	48	64	44	56
3.551	28	44	48	86	4.477	44	64	56	86	5.920	40	44	56	86
3.565	28	48	44	72	4.480	56	40	32	100	5.926	64	48	32	72
3.581	28	40	44	86	4.537	28	48	56	72	5.954	64	40	32	86
3.618	40	72	56	86	4.548	44	72	64	86	5.969	44	48	56	86
3.636	24	44	48	72	4.558	56	40	28	86	5.972	86	48	24	72
3.654	40	56	44	86	4.583	44	64	48	72	6.061	40	44	48	72
3.667	44	48	40	100	4.667	28	40	48	72	6.109	56	44	48	100
3.704	32	48	40	72	4.736	32	44	56	86	6.125	56	40	28	64
3.721	28	56	64	86	4.762	40	56	48	72	6.136	72	44	24	64
3.733	48	100	56	72	4.773	56	44	24	64	6.140	44	40	48	86
3.750	48	64	28	56	4.821	72	56	24	64	6.160	56	40	44	100
3.771	44	56	48	100	4.848	32	44	48	72	6.202	40	48	64	86
3.798	28	48	56	86	4.861	40	64	56	72	6.222	64	40	28	72
3.810	32	56	48	72	4.884	48	64	56	86	6.234	64	44	24	56
3.819	40	64	44	72	4.889	32	40	44	72	6.349	40	56	64	72
3.837	44	64	48	86	4.949	56	44	28	72	6.364	56	44	32	64
3.840	48	40	32	100	4.961	48	72	64	86	6.379	48	56	64	86
3.850	44	100	56	64	5.074	40	44	48	86	6.429	72	56	32	64
3.889	32	64	56	72	5.080	32	56	64	72	6.465	64	44	32	72
3.907	28	40	48	86	5.093	40	48	44	72	6.481	40	48	56	72
3.920	56	40	28	100	5.104	56	48	28	64	6.515	86	44	24	72
3.979	44	72	56	86	5.119	86	56	24	72	6.563	72	48	28	64
3.986	40	56	48	86	5.133	56	48	44	100	6.667	64	56	28	48

For leads up to 6.667 inches.

Gearing for Cutting Worm and Spiral Gears

$$\frac{\text{Lead}}{10} = \frac{\text{Driven}}{\text{Drivers}} = \frac{\text{Second} \times \text{Worm}}{\text{First} \times \text{Screw}}$$

Leads from 6.720 to 12.444 Inches

Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)	Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)	Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)
6.720	56	40	48	100	8.212	86	64	44	72	10.238	86	56	48	72
6.750	72	40	24	64	8.250	48	64	44	40	10.286	72	40	32	56
6.765	40	44	64	86	8.312	64	56	32	44	10.313	72	64	44	48
6.806	56	32	28	72	8.333	48	32	40	72	10.370	56	48	64	72
6.822	44	48	64	86	8.361	86	40	28	72	10.390	64	56	40	44
6.825	86	56	32	72	8.377	86	44	24	56	10.419	56	40	64	86
6.968	86	48	28	72	8.485	48	44	56	72	10.451	86	64	56	72
6.984	44	56	64	72	8.532	86	56	40	72	10.476	64	56	44	48
7.000	56	40	32	64	8.551	86	44	28	64	10.500	56	64	48	40
7.013	72	44	24	56	8.555	44	40	56	72	10.558	86	64	44	56
7.071	40	44	56	72	8.571	72	56	32	48	10.667	48	40	64	72
7.104	48	44	56	86	8.682	64	48	56	86	10.694	56	32	44	72
7.111	64	40	32	72	8.687	86	44	32	72	10.714	72	56	40	48
7.130	44	48	56	72	8.839	72	64	44	56	10.750	86	40	32	64
7.159	72	44	28	64	8.889	56	28	32	72	10.859	86	44	40	72
7.163	44	40	56	86	8.930	48	40	64	86	10.909	72	48	32	44
7.167	86	40	24	72	8.958	86	56	28	48	10.938	56	32	40	64
7.273	64	44	28	56	9.000	72	40	28	56	10.949	86	48	44	72
7.292	56	64	40	48	9.143	64	40	32	56	11.111	64	32	40	72
7.330	86	44	24	64	9.166	48	32	44	72	11.168	86	44	32	56
7.333	44	40	48	72	9.214	86	40	24	56	11.169	72	48	64	86
7.407	40	48	64	72	9.333	48	40	56	72	11.198	86	64	40	48
7.465	86	64	40	72	9.351	72	56	32	44	11.250	72	32	28	56
7.500	72	48	32	64	9.375	72	64	40	48	11.313	56	44	64	72
7.601	86	44	28	72	9.385	86	56	44	72	11.402	86	44	28	48
7.619	48	56	64	72	9.406	86	40	28	64	11.518	86	64	48	56
7.679	86	64	32	56	9.429	48	56	44	40	11.667	56	32	48	72
7.714	72	40	24	56	9.471	56	44	64	86	11.688	72	56	40	44
7.778	64	32	28	72	9.524	64	56	40	48	11.758	86	32	28	64
7.814	48	40	56	86	9.545	72	48	28	44	11.786	72	56	44	48
7.839	86	48	28	64	9.556	86	40	32	72	11.852	64	24	32	72
7.875	72	40	28	64	9.568	72	56	64	86	12.000	72	40	32	48
7.955	56	64	40	44	9.598	86	64	40	56	12.031	56	32	44	64
7.963	86	48	32	72	9.625	56	64	44	40	12.040	86	56	64	72
8.000	64	40	28	56	9.643	72	64	48	56	12.121	64	48	40	44
8.021	56	64	44	48	9.697	64	48	32	44	12.178	72	44	64	86
8.036	72	64	40	56	9.722	56	32	40	72	12.216	86	64	40	44
8.063	86	40	24	64	9.773	86	44	32	64	12.222	48	24	44	72
8.081	40	44	64	72	9.778	44	40	64	72	12.273	72	64	48	44
8.118	48	44	64	86	9.844	72	32	28	64	12.286	86	40	32	56
8.148	44	48	64	72	9.954	86	48	40	72	12.318	86	64	44	48
8.182	72	44	28	56	10.159	64	28	32	72	12.375	72	40	44	64
8.186	44	40	64	86	10.227	72	64	40	44	12.444	56	40	64	72

For leads up to 12.444.

Gearing for Cutting Worm and Spiral Gears

Leads from 12.468 to 24.635 Inches

$$\frac{\text{Lead}}{10} = \frac{\text{Driven}}{\text{Drivers}} = \frac{\text{Second} \times \text{Worm}}{\text{First} \times \text{Screw}}$$

Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)
12.468	64	56	48	44
12.500	56	28	40	64
12.542	86	40	28	48
12.571	64	56	44	40
12.698	64	28	40	72
12.798	86	56	40	48
12.833	56	48	44	40
12.857	72	28	32	64
12.963	56	24	40	72
13.030	86	48	32	44
13.091	72	40	32	44
13.125	56	32	48	64
13.139	86	40	44	72
13.333	64	32	48	72
13.395	72	40	64	86
13.438	86	32	28	56
13.500	72	64	48	40
13.636	72	48	40	44
13.651	86	28	32	72
13.714	64	56	48	40
13.750	56	28	44	64
13.935	86	24	28	72
13.961	86	56	40	44
13.968	64	28	44	72
14.026	72	56	48	44
14.063	72	32	40	64
14.077	86	56	44	48
14.143	72	56	44	40
14.259	56	24	44	72
14.286	64	32	40	56
14.318	72	64	56	44
14.333	86	40	48	72
14.659	86	64	48	44
14.667	64	48	44	40
14.694	72	28	32	56
14.781	86	64	44	40
14.815	64	24	40	72
14.931	86	32	40	72
15.000	56	28	48	64
15.202	86	44	56	72
15.238	64	28	48	72
15.273	56	44	48	40
15.357	86	28	32	64
15.429	72	56	48	40
15.469	72	32	44	64
15.556	64	32	56	72
15.636	86	40	32	44
15.677	86	64	56	48
15.714	64	32	44	56
15.750	72	64	56	40
15.926	86	48	64	72
16.071	72	32	40	56
16.125	86	64	48	40
16.288	86	48	40	44
16.296	64	24	44	72
16.424	86	32	44	72
16.500	72	48	44	40
16.722	86	40	56	72
16.753	86	56	48	44
16.797	86	32	40	64
16.875	72	32	48	64
16.893	86	56	44	40
16.970	64	48	56	44
17.063	86	28	40	72
17.102	86	64	56	44
17.143	72	56	64	48
17.277	86	64	72	56
17.374	86	44	64	72
17.455	64	44	48	40
17.500	56	24	48	64
17.551	86	28	32	56
17.679	72	56	44	32
17.777	64	28	56	72
17.917	86	32	48	72
17.959	64	28	44	56
18.333	64	48	44	32
18.367	72	28	40	56
18.429	86	56	48	40
18.477	86	32	44	64
18.667	64	48	56	40
18.701	72	56	64	44
18.750	72	32	40	48
18.770	86	28	44	72
18.813	86	64	56	40
19.091	72	48	56	44
19.111	86	40	64	72
19.196	86	32	40	56
19.286	72	32	48	56
19.592	64	28	48	56
19.636	72	44	48	40
19.688	72	32	56	64
19.708	86	48	44	40
19.907	86	24	40	72
20.156	86	64	72	48
20.204	72	28	44	56
20.364	64	44	56	40
20.455	72	32	40	44
20.476	86	56	64	48
20.571	72	56	64	40
20.625	72	48	44	32
20.741	64	24	56	72
20.903	86	32	56	72
20.952	64	24	44	56
21.000	72	48	56	40
21.116	86	32	44	56
21.429	72	28	40	48
21.818	72	48	64	44
21.939	86	28	40	56
21.989	86	64	72	44
22.041	72	28	48	56
22.338	86	56	64	44
22.396	86	32	40	48
22.500	72	28	56	64
22.803	86	48	56	44
22.857	64	24	48	56
22.900	72	44	56	40
23.036	86	56	72	48
23.333	64	48	56	32
23.455	86	44	48	40
23.516	86	64	56	32
23.571	72	28	44	48
23.889	86	32	64	72
24.000	72	48	64	40
24.133	86	28	44	56
24.188	86	64	72	40
24.432	86	32	40	44
24.545	72	44	48	32
24.571	86	56	64	40
24.635	86	48	44	32

For leads up to 24.635 inches.

Gearing for Cutting Worm and Spiral Gears

Leads from 24.750 to 80.625 Inches

$$\frac{\text{Lead}}{10} = \frac{\text{Driven}}{\text{Drivers}} = \frac{\text{Second} \times \text{Worm}}{\text{First} \times \text{Screw}}$$

Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)	Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)	Lead of Spiral in Inches	Gear on Worm (Driven)	First Intermediate Gear (Driver)	Second Intermediate Gear (Driven)	Gear for Screw (Driver)
24.750	72	40	44	32	30.857	72	28	48	40	40.952	86	28	64	48
25.083	86	48	56	40	31.111	64	24	56	48	41.143	72	28	64	40
25.130	86	56	72	44	31.273	86	44	64	40	41.806	86	24	56	48
25.455	64	44	56	32	31.354	86	48	56	32	42.232	86	28	44	32
25.595	86	28	40	48	31.500	72	40	56	32	43.000	86	40	64	32
25.714	72	56	64	32	31.852	86	24	64	72	43.636	72	24	64	44
26.061	86	48	64	44	32.000	64	28	56	40	43.977	86	44	72	32
26.182	72	44	64	40	32.250	86	48	72	40	44.675	86	28	64	44
26.250	72	48	56	32	32.570	86	24	40	44	45.000	72	28	56	32
26.327	86	28	48	56	32.727	72	44	64	32	45.666	86	24	56	44
26.667	64	28	56	48	32.847	86	24	44	48	46.071	86	28	72	48
26.875	86	28	56	64	33.507	86	28	48	44	47.778	86	24	64	48
27.000	72	40	48	32	33.780	86	28	44	40	48.000	72	24	64	40
27.302	86	28	64	72	33.939	64	24	56	44	48.375	86	40	72	32
27.364	86	44	56	40	34.205	86	44	56	32	49.143	86	28	64	40
27.500	72	24	44	48	34.286	72	28	64	48	50.167	86	24	56	40
27.643	86	56	72	40	34.554	86	56	72	32	50.260	86	28	72	44
27.922	86	28	40	44	35.000	72	24	56	48	51.429	72	28	64	32
28.000	64	40	56	32	35.102	86	28	64	56	52.121	86	24	64	44
28.052	72	28	48	44	35.182	86	44	72	40	53.750	86	28	56	32
28.155	86	28	44	48	35.833	86	48	64	32	55.286	86	28	72	40
28.636	72	44	56	32	36.000	72	40	64	32	57.333	86	24	64	40
28.667	86	48	64	40	36.857	86	28	48	40	58.636	86	24	72	44
29.091	64	28	56	44	37.403	72	28	64	44	60.000	72	24	64	32
29.318	86	48	72	44	37.625	86	40	56	32	61.429	86	28	64	32
29.388	72	28	64	56	38.182	72	24	56	44	62.708	86	24	56	32
29.563	86	40	44	32	39.091	86	44	64	32	64.500	86	24	72	40
29.861	86	24	40	48	39.417	86	24	44	40	69.107	86	28	72	32
30.000	72	48	64	32	39.490	86	28	72	56	71.667	86	24	64	32
30.234	86	64	72	32	40.000	72	24	64	48	80.625	86	24	72	32
30.714	86	56	64	32	40.313	86	48	72	32					

For leads up to 80.625 inches.

PLAIN AND DIFFERENTIAL INDEXING ON BROWN & SHARPE MILLING MACHINES

THE general arrangement of the universal dividing head is illustrated in Figs. 1, 2, and 3. As indicated by the diagrammatic sketch Fig. 2, the worm wheel *A* is secured to the main spindle of the spiral head and rotated by means of the worm shaft and single-threaded worm *B*. The index plate (having rows of equally spaced holes) remains stationary during the dividing operation, and is fitted with adjustable sector arms which obviate the necessity of counting the number of holes through which the index crank requires to be moved each time a division is made on the surface of the work. The standard ratio between the worm *B* and the worm wheel *A* is 1: 40; and to find the movement of the index crank

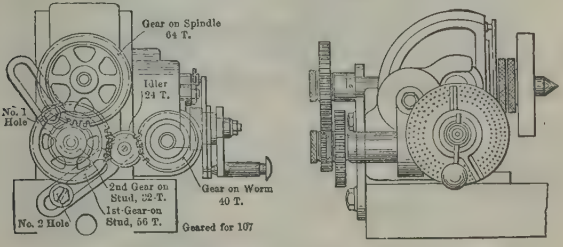


FIG. 1.—Brown and Sharpe Dividing Head Arranged for Differential Indexing

or any required division, the following formula is employed: The movement of the index crank $= \frac{40}{N}$ where N is the number of equal divisions required.

Example: Let it be required to divide the circumference of a piece of work into 48 equal parts.

The movement of the index crank for each division $= \frac{40}{48} = \frac{5}{6}$ *revolutions.*

An index plate having a row of 18 holes would be chosen, and the sector arms set to limit the movement of the index crank to 15 spaces for $\frac{5}{6} = \frac{15}{18}$.

GENERAL PRINCIPLE OF DIFFERENTIAL INDEXING

The number of equal divisions which may be obtained by simple indexing (with the index plates usually provided by milling-machine makers) is strictly limited, and does not meet all the requirements called for in practice.

Differential indexing provides the most convenient way of overcoming this difficulty, this method being simpler than compound indexing. In the differential system the dividing operation is performed as in simple indexing, the only difference being that the index plate instead of remaining stationary during the process of indexing, is made to move relatively to the index crank, being con-

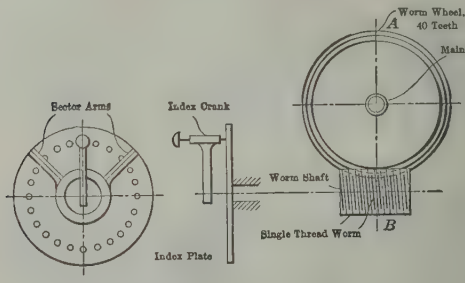


FIG. 2

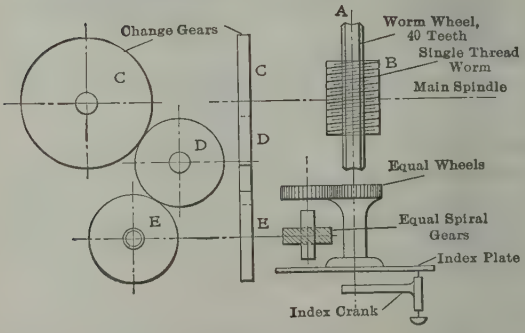


FIG. 3

nected to the main spindle of the spiral head by a set of change gears, which may be arranged to give either a *positive* or *negative* movement to the index plate; whichever is found necessary to determine the *actual* motion which must be given to the index crank in order to satisfy the formula given above for simple indexing: *Actual movement of the index crank* $= \frac{40}{N}$.

The two views in Fig. 1 and the diagram, Fig. 3, will serve to give an idea of the arrangement of the gearing, which is adopted in differential indexing.

For any movement of the index crank the motion is transmitted to the index plate (which is free to rotate on the worm shaft) as follows: The index crank drives through the worm shaft and worm B to the worm wheel A, which in turn transmits the motion through the change gears, spiral gears and equal gears, the last of which is connected directly to the index plate. The last pair of gears being equal and driven through equal spiral gears, whatever number of revolutions are given to the gear E, the index plate will make the same number. It is therefore convenient to consider the revolutions of the gear E, as the revolutions of the index plate in all calculations.

To illustrate the influence of the gearing on the index plate and indexing operation, consider the following example: Required to index for 107 divisions:

If we use the plate having 20 holes and move 8 holes per division, as in simple indexing for 100 divisions, 100 moves will of course be required to rotate the worm 40 turns, which in turn rotates the spindle once. If now we make 107 moves with the index plate fixed as in simple indexing, we will obtain $107 \times \frac{8}{20} = 42.8$ revolutions of the worm, which is 2.8 in excess of what is required. Therefore the index plate must be geared so that it will move back 2.8 turns while the spindle is revolving once; that is, the ratio of the gearing must be 2.8 to 1.

$$\frac{2.8}{1} = \frac{2.8}{2} \times \frac{2}{1}$$

$$\frac{2.8}{2} \times \frac{20}{20} = \frac{56}{40} \qquad \frac{2}{1} \times \frac{32}{32} = \frac{64}{32}.$$

Then $\frac{2.8}{1} = \frac{56}{40} \times \frac{64}{32}$ and the gears will be 64 and 56 for the spindle and first gear on stud, and 40 and 32 for the worm and second gear on stud, as shown in Fig. 1. As compound gears are used, but one idler is required to cause the index plate to move in a direction opposite to that of the crank. For this purpose an idler having 24 teeth is employed.

Formula for Finding the Gear Ratio

A simple formula for the determination of the gear ratio necessary to rotate the index plate as required for any given number of teeth is derived as follows:

Let N equal the number of divisions required to be indexed.

Let n equal some number either greater or smaller than N, which can be obtained directly by simple indexing.

Let $\frac{40}{n}$ equal the index setting; that is the setting of the sector arms for each movement of the index crank;

Then $(n - N) \times \frac{40}{n}$ equals the gear ratio.

If the number chosen for n is greater than the number of divisions required (N) the index plate must be geared to have a positive motion, that is to rotate in the same direction as the index crank. If the number n is less than N the index plate is geared to have a negative motion, that is, to rotate in opposite direction to the crank.

Application of the Formula

Suppose we wish to obtain 63 divisions: choose any number for n which may be obtained by simple indexing, say 60, then

$$(n - N) = (60 - 63) = -3$$

This number (-3) when multiplied by the value of the index setting will give the gear ratio. The index setting equals $\frac{40}{n}$, equals $\frac{40}{60}$, then $(n - N)\frac{40}{n} = -3 \times \frac{40}{60} = -\frac{60}{30}$ or $\frac{2}{1}$ as the gear ratio.

We can therefore use gears of 48 and 24 teeth, the 48 gear being the driver and the 24 gear the follower; that is, the 48 gear being on the spindle and the 24 gear on the worm. As n is smaller than N the idlers are arranged to give a negative movement to the index plate.

The index setting is found above as $\frac{40}{n}$ which equals $\frac{40}{60}$ or $\frac{2}{3}$. We can thus use the 39 hole circle in the index plate and set the sector for 26 holes, this giving the setting as $\frac{26}{39}$ or $\frac{2}{3}$; that is, we set the sector and index pin exactly the same as for simple indexing of 60 divisions.

The tables on the following pages give the dividing head gears for indexing all numbers up to 730.

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
2	Any	20						
3	39	$13\frac{18}{39}$						
4	Any	10						
5	Any	8						
6	39	$6\frac{26}{39}$						
7	49	$5\frac{35}{49}$						
8	Any	5						
9	27	$4\frac{12}{27}$						
10	Any	4						
11	33	$3\frac{21}{33}$						
12	39	$3\frac{18}{39}$						
13	39	$3\frac{8}{39}$						
14	49	$2\frac{42}{49}$						
15	39	$2\frac{26}{39}$						
16	20	$2\frac{10}{20}$						
17	17	$2\frac{6}{17}$						
18	27	$2\frac{6}{27}$						
19	19	$2\frac{2}{19}$						
20	Any	2						
21	21	$1\frac{9}{21}$						
22	33	$1\frac{22}{33}$						
23	23	$1\frac{15}{23}$						
24	39	$1\frac{15}{39}$						
25	20	$1\frac{12}{20}$						
26	39	$1\frac{13}{39}$						
27	27	$1\frac{18}{27}$						
28	49	$1\frac{21}{49}$						
29	29	$1\frac{1}{29}$						
30	39	$1\frac{24}{39}$						
31	31	$1\frac{9}{31}$						
32	20	$1\frac{8}{20}$						
33	33	$1\frac{11}{33}$						
34	17	$1\frac{8}{17}$						
35	49	$1\frac{7}{49}$						
36	27	$1\frac{9}{27}$						
37	37	$1\frac{3}{37}$						
38	19	$1\frac{1}{19}$						
39	39	$1\frac{1}{39}$						
40	Any	1						
41	41	$\frac{40}{41}$						
42	21	$\frac{20}{21}$						

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
43	43	$\frac{40}{43}$						
44	33	$\frac{30}{33}$						
45	27	$\frac{24}{27}$						
46	23	$\frac{20}{23}$						
47	47	$\frac{40}{47}$						
48	18	$\frac{15}{18}$						
49	49	$\frac{40}{49}$						
50	20	$\frac{16}{20}$						
51	17	$\frac{14}{17}$	24			48	24	44
52	39	$\frac{30}{39}$						
53	49	$\frac{35}{49}$	56	40	24	72		
54	27	$\frac{20}{27}$						
55	33	$\frac{24}{33}$						
56	49	$\frac{35}{49}$						
57	21	$\frac{15}{21}$	56			40	24	44
58	29	$\frac{20}{29}$						
59	39	$\frac{28}{39}$	48			32	44	
60	39	$\frac{26}{39}$						
61	39	$\frac{28}{39}$	48			32	24	44
62	31	$\frac{20}{31}$						
63	39	$\frac{26}{39}$	24			48	24	44
64	16	$\frac{10}{16}$						
65	39	$\frac{24}{39}$						
66	33	$\frac{20}{33}$						
67	21	$\frac{14}{21}$	28			48	44	
68	17	$\frac{10}{17}$						
69	20	$\frac{12}{20}$	40			56	24	44
70	49	$\frac{28}{49}$						
71	18	$\frac{10}{18}$	72			40	24	
72	27	$\frac{15}{27}$						
73	21	$\frac{12}{21}$	28			48	24	44
74	37	$\frac{20}{37}$						
75	15	$\frac{8}{15}$						
76	19	$\frac{10}{19}$						
77	20	$\frac{10}{20}$	32			48	44	
78	39	$\frac{20}{39}$						
79	20	$\frac{10}{20}$	48			24	44	
80	20	$\frac{10}{20}$						
81	20	$\frac{10}{20}$	48			24	24	44
82	41	$\frac{20}{41}$						
83	20	$\frac{10}{20}$	3			48	24	44

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
84	21	$\frac{10}{21}$						
85	17	$\frac{8}{17}$						
86	43	$\frac{20}{43}$						
87	15	$\frac{7}{15}$	40			24	24	44
88	33	$\frac{15}{33}$						
89	18	$\frac{8}{18}$	72			32	44	
90	27	$\frac{12}{27}$						
91	39	$\frac{18}{39}$	24			48	24	44
92	23	$\frac{10}{23}$						
93	18	$\frac{8}{18}$	24			32	24	44
94	47	$\frac{20}{47}$						
95	19	$\frac{8}{19}$						
96	21	$\frac{9}{21}$	28			32	24	44
97	20	$\frac{8}{20}$	40			48	44	
98	49	$\frac{20}{49}$						
99	20	$\frac{8}{20}$	56	28	40	32		
100	20	$\frac{8}{20}$						
101	20	$\frac{8}{20}$	72	24	40	48		24
102	20	$\frac{8}{20}$	40			32	24	44
103	20	$\frac{8}{20}$	40			48	24	44
104	39	$\frac{15}{39}$						
105	21	$\frac{8}{21}$						
106	43	$\frac{18}{43}$	86	24	24	48		
107	20	$\frac{8}{20}$	40	56	32	64		24
108	27	$\frac{10}{27}$						
109	16	$\frac{6}{16}$	32			28	24	44
110	33	$\frac{12}{33}$						
111	39	$\frac{14}{39}$	24			72	32	
112	39	$\frac{18}{39}$	24			64	44	
113	39	$\frac{18}{39}$	24			56	44	
114	39	$\frac{18}{39}$	24			48	44	
115	23	$\frac{8}{23}$						
116	29	$\frac{10}{29}$						
117	39	$\frac{18}{39}$	24			24	56	
118	39	$\frac{18}{39}$	48			32	44	
119	39	$\frac{18}{39}$	72			24	44	
120	39	$\frac{18}{39}$						
121	39	$\frac{18}{39}$	72			24	24	44
122	39	$\frac{18}{39}$	48			32	24	44
123	39	$\frac{18}{39}$	24			24	24	44
124	31	$\frac{10}{31}$						

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
125	39	1 3/39	24			40	24	44
126	39	1 3/39	24			48	24	44
127	39	1 3/39	24			56	24	44
128	16	1/16						
129	39	1 3/39	24			72	24	44
130	39	1 3/39						
131	20	1/20	40			28	44	
132	33	1 3/33						
133	21	1 7/21	24			48	44	
134	21	1 7/21	28			48	44	
135	27	1 9/27						
136	17	1/17						
137	21	1 7/21	28			24	56	
138	21	1 7/21	56			32	44	
139	21	1 7/21	56	32	48	24		
140	49	1 14/49						
141	18	1/18	48			40	44	
142	21	1 7/21	56			32	24	44
143	21	1 7/21	28			24	24	44
144	18	1/18						
145	29	1 9/29						
146	21	1 7/21	28			48	24	44
147	21	1 7/21	24			48	24	44
148	37	1 9/37						
149	21	1 7/21	28			72	24	44
150	15	1/15						
151	20	1/20	32			72	44	
152	19	1/19						
153	20	1/20	32			56	44	
154	20	1/20	32			48	44	
155	31	1 7/31						
156	39	1 13/39						
157	20	1/20	32			24	56	
158	20	1/20	48			24	44	
159	20	1/20	64	32	56	28		
160	20	1/20						
161	20	1/20	64	32	56	28		24
162	20	1/20	48			24	24	44
163	20	1/20	32			24	24	44
164	41	1 21/41						
165	33	1 8/33						

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
166	20	$\frac{5}{20}$	32			48	24	44
167	20	$\frac{5}{20}$	32			56	24	44
168	21	$\frac{5}{21}$						
169	20	$\frac{5}{20}$	32			72	24	44
170	17	$\frac{5}{17}$						
171	21	$\frac{5}{21}$	56			40	24	44
172	43	$\frac{10}{43}$						
173	18	$\frac{5}{18}$	72	56	32	64		
174	18	$\frac{5}{18}$	24			32	56	
175	18	$\frac{5}{18}$	72	40	32	64		
176	18	$\frac{5}{18}$	72	24	24	64		
177	18	$\frac{5}{18}$	72			48	24	
178	18	$\frac{5}{18}$	72			32	44	
179	18	$\frac{5}{18}$	72	24	48	32		
180	18	$\frac{5}{18}$						
181	18	$\frac{5}{18}$	72	24	48	32		24
182	18	$\frac{5}{18}$	72			32	24	44
183	18	$\frac{5}{18}$	48			32	24	44
184	23	$\frac{5}{23}$						
185	37	$\frac{8}{37}$						
186	18	$\frac{5}{18}$	48			64	24	44
187	18	$\frac{5}{18}$	72	48	24	56		24
188	47	$\frac{10}{47}$						
189	18	$\frac{5}{18}$	32			64	24	44
190	19	$\frac{5}{19}$						
191	20	$\frac{5}{20}$	40			72	24	
192	20	$\frac{5}{20}$	40			64	44	
193	20	$\frac{5}{20}$	40			56	44	
194	20	$\frac{5}{20}$	40			48	44	
195	39	$\frac{8}{39}$						
196	49	$\frac{10}{49}$						
197	20	$\frac{5}{20}$	40			24	56	
198	20	$\frac{5}{20}$	56	28	40	32		
199	20	$\frac{5}{20}$	100	40	64	32		
200	20	$\frac{5}{20}$						
201	20	$\frac{5}{20}$	72	24	40	24		24
202	20	$\frac{5}{20}$	72	24	40	48		24
203	20	$\frac{5}{20}$	40			24	24	44
204	20	$\frac{5}{20}$	40			32	24	44
205	41	$\frac{8}{41}$						
206	20	$\frac{5}{20}$	40			48	24	44

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
207	20	4/20	40			56	24	44
208	20	4/20	40			64	24	44
209	20	4/20	40			72	24	44
210	21	4/21						
211	16	8/16	64			28	44	
212	43	8/43	86	24	24	48		
213	27	5/27	72			40	44	
214	20	4/20	40	56	32	64		24
215	43	8/43						
216	27	5/27						
217	21	4/21	48			64	24	44
218	16	8/16	64			56	24	44
219	21	4/21	28			48	24	44
220	33	6/33						
221	17	8/17	24			24	56	
222	18	8/18	24			72	44	
223	43	8/43	86	48	24	64		24
224	18	8/18	24			64	44	
225	27	6/27	24			40	24	44
226	18	8/18	24			56	44	
227	49	8/49	56	64	28	72		
228	18	8/18	24			48	44	
229	18	8/18	24			44	48	
230	23	4/23						
231	18	8/18	32			48	44	
232	29	5/29						
233	18	8/18	48			56	44	
234	18	8/18	24			24	56	
235	47	8/47						
236	18	8/18	48			32	44	
237	18	8/18	48			24	44	
238	18	8/18	72			24	44	
239	18	8/18	72	24	64	32		
240	18	8/18						
241	18	8/18	72	24	64	32		24
242	18	8/18	72			24	24	44
243	18	8/18	64			32	24	44
244	18	8/18	48			32	24	44
245	49	8/49						
246	18	8/18	24			24	24	44
247	18	8/18	48			56	24	44

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
248	31	5/31						
249	18	8/18	32			48	24	44
250	18	8/18	24			40	24	44
251	18	8/18	48	44	32	64		24
252	18	8/18	24			48	24	44
253	33	5/33	24			40	56	
254	18	8/18	24			56	24	44
255	18	8/18	48	40	24	72		24
256	18	8/18	24			64	24	44
257	49	8/49	56	48	28	64		24
258	43	7/43	32			64	24	44
259	21	8/21	24			72	44	
260	39	6/39						
261	29	4/29	48	64	24	72		
262	20	8/20	40			28	44	
263	49	8/49	56	64	28	72		24
264	33	5/33						
265	21	8/21	56	40	24	72		
266	21	8/21	32			64	44	
267	27	4/27	72			32	44	
268	21	8/21	28			48	44	
269	20	8/20	64	32	40	28		24
270	27	4/27						
271	21	8/21	56			72	24	
272	21	8/21	56			64	24	
273	21	8/21	24			24	56	
274	21	8/21	56			48	44	
275	21	8/21	56			40	44	
276	21	8/21	56			32	44	
277	21	8/21	56			24	44	
278	21	8/21	56	32	48	24		
279	27	4/27	24			32	24	44
280	49	7/49						
281	21	8/21	72	24	56	24		24
282	43	6/43	86	24	24	56		
283	21	8/21	56			24	24	44
284	21	8/21	56			32	24	44
285	21	8/21	56			40	24	44
286	21	8/21	56			48	24	44
287	21	8/21	24			24	24	44
288	21	8/21	28			32	24	44

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
289	21	3/21	56			72	24	44
290	29	2/29						
291	15	1/15	40			48	44	
292	21	3/21	28			48	24	44
293	15	1/15	48	32	40	56		
294	21	3/21	24			48	24	44
295	15	1/15	48			32	44	
296	37	2/37						
297	33	4/33	28	48	24	56		
298	21	3/21	28			72	24	44
299	23	2/23	24			24	56	
300	15	2/15						
301	43	6/43	24			48	24	44
302	16	2/16	32			72	24	
303	15	2/15	72	24	40	48		24
304	16	2/16	24			48	44	
305	15	2/15	48			32	24	44
306	15	2/15	40			32	24	44
307	15	2/15	72	48	40	56		24
308	16	2/16	32			48	44	
309	15	2/15	40			48	24	44
310	31	4/31						
311	16	2/16	64	24	24	72		
312	39	3/39						
313	16	2/16	32			28	56	
314	16	2/16	32			24	56	
315	16	2/16	64			40	24	
316	16	2/16	64			32	44	
317	16	2/16	64			24	44	
318	16	2/16	56	28	48	24		
319	29	4/29	48	64	24	72		24
320	16	2/16						
321	16	2/16	72	24	64	24		24
322	23	3/23	32			64	24	44
323	16	2/16	64			24	24	44
324	16	2/16	64			32	24	44
325	16	2/16	64			40	24	44
326	16	2/16	32			24	24	44
327	16	2/16	32			28	24	44
328	41	5/41						
329	16	2/16	64	24	24	72		24

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
330	33	4/33						
331	16	2/16	64	44	24	48		24
332	16	2/16	32			48	24	44
333	18	2/18	24			72	44	
334	16	2/16	32			56	24	44
335	33	4/33	72	48	44	40		24
336	16	2/16	32			64	24	44
337	43	5/43	86	40	32	56		
338	16	2/16	32			72	24	44
339	18	2/18	24			56	44	
340	17	2/17						
341	43	5/43	86	24	32	40		
342	18	2/18	32			64	44	
343	15	2/16	40	64	24	86		24
344	43	5/43						
345	18	2/18	24			40	56	
346	18	2/18	72	56	32	64		
347	43	5/43	86	24	32	40		24
348	18	2/18	24			32	56	
349	18	2/18	72	44	24	48		
350	18	2/18	72	40	32	64		
351	18	2/18	24			24	56	
352	18	2/18	72	24	24	64		
353	18	2/18	72			56	24	
354	18	2/18	72			48	24	
355	18	2/18	72			40	24	
356	18	2/18	72			32	24	
357	18	2/18	72			24	44	
358	18	2/18	72	32	48	24		
359	43	5/43	86	48	32	100		24
360	18	2/18						
361	19	2/19	32			64	44	
362	18	2/18	72	28	56	32		24
363	18	2/18	72			24	24	44
364	18	2/18	72			32	24	44
365	20	2/20	32	48	24	56		
366	18	2/18	48			32	24	44
367	18	2/18	72			56	24	24
368	18	2/18	72	24	24	64		24
369	41	4/41	32	56	28	64		
370	37	4/37						

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
371	21	$\frac{2}{21}$	32	56	24	64		
372	18	$\frac{2}{18}$	48			64	24	44
373	20	$\frac{2}{20}$	40	48	32	72		
374	18	$\frac{2}{18}$	72	64	32	56		24
375	18	$\frac{2}{18}$	24			40	24	44
376	47	$\frac{2}{47}$						
377	29	$\frac{2}{29}$	24			24	56	
378	18	$\frac{2}{18}$	32			64	24	44
379	20	$\frac{2}{20}$	48	56	40	72		
380	19	$\frac{2}{19}$						
381	18	$\frac{2}{18}$	24			56	24	44
382	20	$\frac{2}{20}$	40			72	24	
383	20	$\frac{2}{20}$	40			68[1]	44	
384	20	$\frac{2}{20}$	40			64	44	
385	20	$\frac{2}{20}$	32			48	44	
386	20	$\frac{2}{20}$	40			56	44	
387	43	$\frac{1}{43}$	32	56	28	64		
388	20	$\frac{2}{20}$	40			48	44	
389	20	$\frac{2}{20}$	40			44	56	
390	39	$\frac{2}{39}$						
391	20	$\frac{2}{20}$	48	24	40	72		
392	49	$\frac{2}{49}$						
393	20	$\frac{2}{20}$	40			28	44	
394	20	$\frac{2}{20}$	40			24	56	
395	20	$\frac{2}{20}$	64			32	44	
396	20	$\frac{2}{20}$	56	28	40	32		
397	20	$\frac{2}{20}$	64	24	40	32		
398	20	$\frac{2}{20}$	100	40	64	32		
399	21	$\frac{2}{21}$	32			64	44	
400	20	$\frac{2}{20}$						
401	21	$\frac{2}{21}$	56	32	24	76[1]		
402	21	$\frac{2}{21}$	28			48	44	
403	20	$\frac{2}{20}$	64	24	40	32		24
404	20	$\frac{2}{20}$	72	24	40	48		24
405	20	$\frac{2}{20}$	64			32	24	44
406	20	$\frac{2}{20}$	40			24	24	44
407	20	$\frac{2}{20}$	40			28	24	44
408	20	$\frac{2}{20}$	40			32	24	44
409	20	$\frac{2}{20}$	40	24	32	48		24
410	41	$\frac{2}{41}$						

NOTE. Special gears in this and following tables are 46, 47, 52, 58, 68, 70, 76, 84.

[1] Special gear.

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
411	21	$\frac{2}{21}$	28			24	56	
412	20	$\frac{2}{20}$	40			48	24	44
413	21	$\frac{2}{21}$	48			32	44	
414	21	$\frac{2}{21}$	56			32	44	
415	20	$\frac{2}{20}$	32			48	24	44
416	20	$\frac{2}{20}$	40			64	24	44
417	21	$\frac{2}{21}$	56	32	48	24		
418	20	$\frac{2}{20}$	40			72	24	44
419	33	$\frac{3}{33}$	44	28	24	72		
420	21	$\frac{2}{21}$						
421	20	$\frac{2}{20}$	48	56	40	72		24
422	20	$\frac{2}{20}$	40	44	32	64		24
423	21	$\frac{2}{21}$	72	24	56	48		24
424	43	$\frac{4}{43}$	86	24	24	48		
425	21	$\frac{2}{21}$	72	48	56	40		24
426	21	$\frac{2}{21}$	56			32	24	44
427	20	$\frac{2}{20}$	40	48	32	72		24
428	20	$\frac{2}{20}$	40	56	32	64		24
429	21	$\frac{2}{21}$	28			24	24	44
430	43	$\frac{4}{43}$						
431	21	$\frac{2}{21}$	72	44	28	48		24
432	20	$\frac{2}{20}$	40	56	28	64		24
433	20	$\frac{2}{20}$	40	44	24	72		24
434	21	$\frac{2}{21}$	48			64	24	44
435	21	$\frac{2}{21}$	28			40	24	44
436	20	$\frac{2}{20}$	40	48	24	72		24
437	23	$\frac{2}{23}$	32			64	44	
438	21	$\frac{2}{21}$	28			48	24	44
439	43	$\frac{4}{43}$	86	24	24	72		24
440	33	$\frac{3}{33}$						
441	21	$\frac{2}{21}$	32			64	24	44
442	20	$\frac{2}{20}$	40	56	24	72		24
443	20	$\frac{2}{20}$	40	48	24	86		24
444	21	$\frac{2}{21}$	56	48	24	64		24
445	33	$\frac{3}{33}$	64	32	44	40		24
446	33	$\frac{3}{33}$	44			24	24	48
447	21	$\frac{2}{21}$	28			72	24	44
448	20	$\frac{2}{20}$	40	64	24	72		24
449	33	$\frac{3}{33}$	64	32	44	72		24
450	33	$\frac{3}{33}$	44			40	24	32

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
451	33	8/33	24			24	24	44
452	33	8/33	44			48	24	40
453	33	8/33	44			52 [1]	24	40
454	49	4/49	56	64	28	72		
455	49	4/49	28	40	32	64		
456	21	2/21	56	64	24	72		24
457	33	8/33	44			68 [1]	24	40
458	33	8/33	44			72	24	24
459	27	2/27	24	48	24	72		
460	23	2/23						
461	33	8/33	44	28	24	72		24
462	33	8/33	32			64	24	44
463	21	2/21	56	64	24	86		24
464	33	8/33	44	48	28	56		24
465	33	8/33	44	24	24	100		24
466	49	4/49	56	48	28	64		
467	33	8/33	44	48	32	72		24
468	39	8/39	28	48	24	56		
469	49	4/49	28			48	44	
470	47	4/47						
471	49	4/49	56	32	28	76 [1]		
472	49	4/49	56	32	28	72		
473	33	8/33	48	64	32	72		24
474	49	4/49	56	32	28	64		
475	49	4/49	56	40	28	48		
476	49	4/49	56			64	24	
477	27	2/27	24	48	24	56		
478	49	4/49	56	24	28	64		
479	49	4/49	56	32	28	44		
480	49	4/49	56	32	28	40		
481	37	2/37	24			24	56	
482	33	8/33	44	56	24	72		24
483	49	4/49	56			32	44	
484	49	4/49	56	24	28	32		
485	23	2/23	46 [1]	24	24	100		24
486	27	2/27	32	56	28	64		
487	39	8/39	24	72	52 [1]	44		
488	33	8/33	44	64	24	72		24
489	23	2/23	46 [1]	58 [1]	32	64		24
490	49	4/49						

[1] Special gear.

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
491	33	8/33	44	68 [1]	24	72		24
492	41	8/41	28	48	24	56		
493	29	2/29	32	64	24	72		
494	39	8/39	32			64	44	
495	27	2/27	32	40	24	64		
496	49	4/49	56	24	28	32		24
497	49	4/49	56			32	24	44
498	27	2/27	48	56	24	64		
499	49	4/49	56	24	28	48		24
500	49	4/49	56	32	28	40		24
501	49	4/49	56	32	28	44		24
502	49	4/49	56	32	28	48		24
503	23	2/23	46 [1]	64	32	86		24
504	49	4/49	56			64	24	24
505	49	4/49	56	40	28	48		24
506	49	4/49	56	32	28	64		24
507	39	8/39	24			24	56	
508	49	4/49	56	32	28	72		24
509	49	4/49	56	32	28	76 [1]		24
510	49	4/49	56	40	28	64		24
511	49	4/49	28			48	24	44
512	49	4/49	56	44	28	64		24
513	27	2/27	32			64	44	
514	49	4/49	56	48	28	64		24
515	27	2/27	72	32	24	100		
516	43	8/43	32	56	28	64		
517	49	4/49	56	48	28	72		24
518	49	4/49	28			64	24	44
519	27	2/27	72	56	32	64		
520	39	8/39						
521	27	2/27	72	76 [1]	48	64		
522	29	2/29	48	64	24	72		
523	27	2/27	72	68 [1]	48	64		
524	27	2/27	72	32	24	64		
525	27	2/27	72	40	32	64		
526	49	4/49	56	64	28	72		24
527	31	8/31	32	64	24	72		
528	27	2/27	72	24	24	64		
529	27	2/27	72	44	48	64		
530	15	1/15	24	56	32	64		

[1] Special gear.

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
531	27	$\frac{2}{27}$	72			48	24	
532	27	$\frac{2}{27}$	72	32	48	64		
533	27	$\frac{2}{27}$	72	32	48	56		
534	27	$\frac{2}{27}$	72			32	44	
535	27	$\frac{2}{27}$	72	32	48	40		
536	39	$\frac{2}{39}$	52 [1]			64	24	44
537	27	$\frac{2}{27}$	72	28	56	32		
538	29	$\frac{2}{29}$	58 [1]	56	24	72		
539	49	$\frac{4}{49}$	28	48	24	56		24
540	27	$\frac{2}{27}$						
541	39	$\frac{2}{39}$	52 [1]	56	32	48		24
542	39	$\frac{2}{39}$	52 [1]	44	32	64		24
543	27	$\frac{2}{27}$	72	24	48	32		24
544	15	$\frac{1}{15}$	40	56	24	64		
545	15	$\frac{1}{15}$	32	44	24	64		
546	39	$\frac{3}{39}$	32			64	24	44
547	27	$\frac{2}{27}$	72	32	48	56		24
548	27	$\frac{2}{27}$	72	32	48	64		24
549	27	$\frac{2}{27}$	72			48	24	24
550	15	$\frac{1}{15}$	32	40	24	64		
551	29	$\frac{2}{29}$	32			64	44	
552	27	$\frac{2}{27}$	72	24	24	64		24
553	49	$\frac{4}{49}$	28	48	24	72		24
554	27	$\frac{2}{27}$	72	56	48	64		24
555	15	$\frac{1}{15}$	24			72	44	
556	15	$\frac{1}{15}$	24	44	40	64		
557	15	$\frac{1}{15}$	40	32	24	86		
558	27	$\frac{2}{27}$	48			64	24	44
559	39	$\frac{2}{39}$	24			72	24	44
560	43	$\frac{3}{43}$	86	40	32	64		
561	27	$\frac{2}{27}$	72	56	32	64		24
562	27	$\frac{2}{27}$	72	44	24	64		24
563	29	$\frac{2}{29}$	58 [1]			68 [1]	44	
564	43	$\frac{3}{43}$	86	24	24	56		
565	15	$\frac{1}{15}$	24			56	44	
566	43	$\frac{3}{43}$	86	24	24	44		
567	15	$\frac{1}{15}$	32	44	40	64		
568	15	$\frac{1}{15}$	40	32	24	64		
569	29	$\frac{2}{29}$	58 [1]			44	24	
570	15	$\frac{1}{15}$	32			64	44	

[1] Special gear.

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear Stud		No. 1 Hole	No. 2 Hole
571	43	$\frac{8}{43}$	86	28	64	32		
572	15	$\frac{1}{15}$	40	28	24	64		
573	15	$\frac{1}{15}$	40			72	24	
574	41	$\frac{8}{41}$	32			64	24	44
575	15	$\frac{1}{15}$	24			40	44	
576	15	$\frac{1}{15}$	40			64	24	
577	43	$\frac{8}{43}$	86	32	64	44		24
578	15	$\frac{1}{15}$	48	44	40	64		
579	15	$\frac{1}{15}$	40			56	44	
580	29	$\frac{2}{29}$						
581	15	$\frac{1}{15}$	48	32	40	76 [1]		
582	15	$\frac{1}{15}$	40			48	44	
583	27	$\frac{8}{27}$	72	64	24	86		24
584	15	$\frac{1}{15}$	48	32	40	64		
585	15	$\frac{1}{15}$	24			24	56	
586	15	$\frac{1}{15}$	72	48	40	56		
587	29	$\frac{8}{29}$	58 [1]			28	24	44
588	15	$\frac{1}{15}$	40			32	44	
589	15	$\frac{1}{15}$	72	44	40	48		
590	15	$\frac{1}{15}$	48			32	44	
591	15	$\frac{1}{15}$	40			24	44	
592	16	$\frac{1}{16}$	24			72	44	
593	15	$\frac{1}{15}$	72	28	40	48		
594	33	$\frac{8}{33}$	32	56	28	64		
595	15	$\frac{1}{15}$	72			24	44	
596	15	$\frac{1}{15}$	72	24	40	32		
597	33	$\frac{8}{33}$	44	56	24	72		
598	16	$\frac{1}{16}$	64	56	24	72		
599	43	$\frac{8}{43}$	86	44	24	84		24
600	15	$\frac{1}{15}$						
601	29	$\frac{8}{29}$	58 [1]	56	48	72		24
602	43	$\frac{8}{43}$	32			64	24	44
603	15	$\frac{1}{15}$	72	24	40	24		24
604	16	$\frac{1}{16}$	32			72	24	
605	15	$\frac{1}{15}$	72			24	24	44
606	15	$\frac{1}{15}$	72	24	40	48		24
607	15	$\frac{1}{15}$	72	28	40	48		24
608	16	$\frac{1}{16}$	32			64	44	
609	15	$\frac{1}{15}$	40			24	24	44
610	15	$\frac{1}{15}$	48			32	24	44

[1] Gear Special.

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	No. 2 Hole	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
611	15	1 15	72	44	40	48		24
612	15	1 15	40			32	24	44
613	16	1 16	64	48	32	72		
614	15	1 15	72	48	40	56		24
615	15	1 15	24			24	24	44
616	16	1 16	32			48	44	
617	33	2 33	44	32	24	86		
618	15	1 15	40			48	24	44
619	16	1 16	48	28	32	72		
620	31	2 31						
621	15	1 15	40			56	24	44
622	16	1 16	64	24	24	72		
623	16	1 16	64	24	24	68 [1]		
624	16	1 16	24			24	56	
625	15	1 15	24			40	24	44
626	16	1 16	32			28	56	
627	15	1 15	40			72	24	44
628	16	1 16	32			24	56	
629	16	1 16	64			44	24	
630	16	1 16	64			40	24	
631	16	1 16	64	28	56	72		
632	16	1 16	64			32	44	
633	16	1 16	64			28	44	
634	16	1 16	64			24	44	
635	15	1 15	24			56	24	44
636	16	1 16	56	28	48	24		
637	49	3 49	24			24	56	
638	29	2 29	48	64	24	72		24
639	33	2 33	44	28	32	64		
640	16	1 16						
641	33	2 33	44	32	48	76 [1]		
642	16	1 16	72	24	64	24		24
643	16	1 16	64	28	56	24		24
644	49	3 49	56			32	44	
645	15	1 15	24			72	24	44
646	16	1 16	64			24	24	44
647	16	1 16	64			28	24	44
648	16	1 16	64			32	24	44
649	33	2 33	72			48	24	
650	16	1 16	64			40	24	44

[1] Special gear.

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	No. 2 Hole	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
651	16	1/16	64			44	24	24
652	16	1/16	32			24	24	44
653	33	3/33	72	28	44	48		
654	16	1/16	64			56	24	44
655	16	1/16	64	40	32	48		24
656	16	1/16	24			24	24	44
657	18	1/18	32	48	24	56		
658	16	1/16	64	24	24	72		24
659	16	1/16	64	24	24	76[1]		24
660	33	2/33						
661	16	1/16	64	56	48	72		24
662	16	1/16	64	44	24	48		24
663	17	1/17	24			24	56	
664	16	1/16	32			48	24	44
665	49	3/49	56			40	24	44
666	18	1/18	24			72	44	
667	16	1/16	64	48	32	72		24
668	16	1/16	32			56	24	44
669	33	3/33	44			24	24	24
670	33	2/33	72	48	44	40		24
671	33	2/33	72			48	24	24
672	18	1/18	24			64	44	
673	16	1/16	48	44	32	72		24
674	33	2/33	72	56	44	48		24
675	33	3/33	44			40	24	24
676	16	1/16	32			72	24	44
677	18	1/18	48	32	24	86		
678	18	1/18	24			56	44	
679	49	3/49	28			44	24	40
680	17	1/17						
681	33	2/33	44			56	24	24
682	33	3/33	48			64	24	24
683	16	1/16	32			86	24	44
684	18	1/18	32			64	44	
685	18	1/18	24	56	48	40		
686	15	1/15	40	64	24	86		24
687	18	1/18	24			44	48	
688	16	1/16	24			72	24	44
689	39	3/39	24	48	24	56		
690	18	1/18	24			40	56	

[1] Special gear.

Number of Divisions	Index Circle	No. of Turns of Index	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
				First Gear on Stud	Second Gear on Stud		No. 1 Hole	No. 2 Hole
691	18	1/18	48	32	24	58 [1]		
692	18	1/18	72	56	32	64		
693	18	1/18	32			48	44	
694	17	1/17	68 [1]			56	24	44
695	18	1/18	72	24	24	100		
696	18	1/18	24			32	56	
697	17	1/17	24			24	24	44
698	18	1/18	72	44	24	48		
699	18	1/18	48			56	44	
700	18	1/18	72	40	32	64		
701	17	1/17	68 [1]	48	32	56		24
702	18	1/18	24			24	56	
703	19	1/19	24			72	44	
704	18	1/18	72	24	24	64		
705	18	1/18	48			40	44	
706	18	1/18	72			56	24	
707	18	1/18	72			52 [1]	24	
708	18	1/18	72			48	24	
709	18	1/18	72			44	24	
710	18	1/18	72			40	24	
711	18	1/18	64			32	44	
712	18	1/18	72			32	24	
713	18	1/18	72			28	44	
714	18	1/18	72			24	44	
715	18	1/18	72	32	64	40		
716	18	1/18	72	28	56	32		
717	18	1/18	72	24	64	32		
718	33	3/33	44	58 [1]	24	64		24
719	17	1/17	68 [1]	52 [1]	24	72		24
720	18	1/18						
721	21	1/21	24	64	32	68 [1]		
722	19	1/19	32			64	44	
723	18	1/18	72	24	64	32		24
724	18	1/18	72	28	56	32		24
725	18	1/18	72	24	48	40		24
726	18	1/18	72			24	24	44
727	18	1/18	72			28	24	44
728	18	1/18	72			32	24	44
729	18	1/18	64			32	24	44
730	20	2/20	32	48	24	56		

[1] Special gear.

Table for Cutting Racks on Cincinnati Milling Machines

(Using the Table Feed Screw for Making Division)

Pitch 2		Pitch 2¼		Pitch 2½		Pitch 2¾		Pitch 3		Pitch 3½		Pitch 4		Pitch 5		Pitch 6		Pitch 7		Pitch 8		Pitch 9	
Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths
6	71	5	146	5	7	4	142	4	47	3	148	3	35	2	128	2	24	1	199	1	143	1	99
6	142	5	42	5	14	4	34	4	94	3	46	3	70	2	6	2	48	1	148	1	36	1	198
6	213	5	188	5	21	4	176	4	141	3	194	3	105	2	134	2	72	1	97	1	179	1	47
6	34	5	84	5	28	4	68	4	188	3	92	3	140	2	12	2	96	1	46	1	72	1	146
6	105	5	230	5	35	4	210	4	235	3	240	3	175	2	140	2	120	1	245	1	215	1	245
6	176	5	126	5	42	4	102	4	32	3	138	3	210	2	18	2	144	1	194	1	108	1	94
6	247	5	22	5	49	4	244	4	79	3	36	3	245	2	146	2	168	1	143	1	1	1	193
6	68	5	168	5	56	4	136	4	126	3	184	3	30	2	24	2	192	1	92	1	144	1	42
6	139	5	64	5	63	4	28	4	173	3	82	3	65	2	152	2	216	1	41	1	37	1	141
6	210	5	210	5	70	4	170	4	220	3	230	3	100	2	30	2	240	1	240	1	180	1	240

Directions.—For example: To cut a 9-pitch rack, adjust the work to the cutter and set the micrometer dial of the lead screw to zero.

For the next tooth turn the lead screw crank through one complete revolution plus an additional amount until the micrometer dial reads 99 thousandths. For the following tooth turn the lead screw crank through one revolution and continue until the micrometer reads 198 thousandths, and so on until you reach the last number in above table; then without moving the lead screw set the micrometer dial to zero and commence over again, continuing as before.

To cut a 4-pitch rack the first spacing is 3 revolutions, 35 thousandths; the second 3 revolutions, and pass on to 70 thousandths and so on.

TABLE FOR CUTTING RACKS ON CINCINNATI MILLING MACHINES—(*Continued*)
(Using the Table Feed Screw for Making Divisions)

Pitch 10		Pitch 11		Pitch 12		Pitch 14	Pitch 16	Pitch 18	Pitch 20	Pitch 22	Pitch 24	Pitch 26	Pitch 28	Pitch 30	Pitch 32	Pitch 36	Pitch 40	Pitch 48
Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths
1	64	1	36	1	12	224	196	175	157	143	131	121	112	105	98	87	79	65
1	128	1	72	1	24	198	142	100	64	36	12	242	224	210	196	174	159	130
1	192	1	108	1	36	172	88	25	221	179	143	113	86	65	44	11	237	195
1	6	1	144	1	48	146	34	200	128	72	24	234	198	170	142	98	66	10
1	70	1	180	1	60	120	230	125	35	215	155	105	60	25	240	185	145	75
1	134	1	216	1	72	94	176	50	192	108	36	226	172	130	88	22	224	140
1	198	1	2	1	84	68	122	225	99	1	167	97	34	235	186	109	53	205
1	12	1	38	1	96	42	68	150	6	144	48	218	146	90	34	196	132	20
1	76	1	74	1	108	16	14	75	163	37	179	89	8	195	132	33	211	85
1	140	1	110	1	120	240	210	250	70	180	60	210	120	50	230	120	40	150

DIRECTIONS.—For example: To cut a 32-pitch rack adjust the work to the cutter and set the micrometer dial of the lead screw to zero.

For the next tooth turn the lead screw crank until the micrometer reads 98 thousandths; for the following tooth continue to turn until the reading is 196 thousandths, for the next, 44 thousandths and so on until you reach the last number in above table; then without moving the lead screw set the micrometer to zero, and commence over again, continuing as before.

For a pitch requiring one or more than one revolution of the screw, follow instructions given on preceding page.

TABLE FOR CUTTING RACKS ON CINCINNATI MILLING MACHINES
(*Continued*)
(Using the Cross Screw for Making Divisions)

Pitch 2		Pitch 2¼		Pitch 2½		Pitch 2¾		Pitch 3		Pitch 3½		Pitch 4		Pitch 5	
Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths
7	171	6	196	6	57	5	142	5	47	4	98	3	185	3	28
7	142	6	192	6	114	5	84	5	94	4	196	3	170	3	56
7	113	6	188	6	171	5	26	5	141	4	94	3	155	3	84
7	84	6	184	6	28	5	168	5	188	4	192	3	140	3	112
7	55	6	180	6	85	5	110	5	35	4	90	3	125	3	140
7	26	6	176	6	142	5	52	5	82	4	188	3	110	3	168
7	197	6	172	6	199	5	194	5	129	4	86	3	95	3	196
7	168	6	168	6	56	5	136	5	176	4	184	3	80	3	24
7	139	6	164	6	113	5	78	5	23	4	82	3	65	3	52
7	110	6	160	6	170	5	20	5	70	4	180	3	50	3	80

Pitch 6		Pitch 7		Pitch 8		Pitch 9		Pitch 10		Pitch 11		Pitch 12		Pitch 14	
Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths	Revolutions	Thousandths
2	124	2	49	1	193	1	149	1	114	1	86	1	62	1	24
2	48	2	98	1	186	1	98	1	28	1	172	1	124	1	48
2	172	2	147	1	179	1	47	1	142	1	58	1	186	1	72
2	96	2	196	1	172	1	196	1	56	1	144	1	48	1	96
2	20	2	45	1	165	1	145	1	170	1	30	1	110	1	120
2	144	2	94	1	158	1	94	1	84	1	116	1	172	1	144
2	68	2	143	1	151	1	43	1	198	1	2	1	34	1	168
2	192	2	192	1	144	1	192	1	112	1	88	1	96	1	192
2	116	2	41	1	137	1	141	1	26	1	174	1	158	1	16
2	40	2	90	1	130	1	90	1	140	1	60	1	20	1	40

TABLE FOR CUTTING RACKS ON CINCINNATI MILLING MACHINES
(*Continued*)
(Using the Cross Screw for Making Divisions)

Pitch 16	Pitch 18	Pitch 20	Pitch 22	Pitch 24	Pitch 26	Pitch 28	Pitch 30	Pitch 32	Pitch 36	Pitch 40	Pitch 48
Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths	Thousandths
196	175	157	143	131	121	112	105	98	87	89	65
192	150	114	86	62	42	24	10	196	174	158	130
188	125	71	29	193	163	136	115	94	61	37	195
184	100	28	172	124	84	48	20	192	148	116	60
180	75	185	115	55	5	160	125	90	35	195	125
176	50	142	58	186	126	72	30	188	122	74	190
172	25	99	1	117	47	184	135	86	9	153	55
168	0	56	144	48	168	96	40	184	96	32	120
164	175	13	87	179	89	8	145	82	183	111	185
160	150	170	30	110	10	120	50	180	70	190	50

DIRECTIONS.—For example: To cut a 16-pitch rack, adjust the work of the cutter and set the micrometer dial of cross screw to zero. For the next tooth turn the cross screw crank until the micrometer reads 196 thousandths; for the following tooth continue to turn until the reading is 192 thousandths; and so on until you reach the last number in the above table; then without moving the cross screw set the micrometer dial to zero, and commence over again, continuing as before. For cases in which one or more revolutions are required, make the number of revolutions and the necessary number of thousandths beyond for each tooth, as shown in the table. For example: To cut a 3-pitch rack. Adjust the work to the cutter and set the micrometer dial on the cross screw to zero. Then mill the first tooth. For the next tooth, turn the cross screw crank through five complete revolutions, plus an additional amount until the micrometer dial reads 47 thousandths. When this tooth has been cut, index for the next tooth by turning the cross screw crank through five complete revolutions again and continue until the micrometer dial reads 94 thousandths. For the next spacing make five revolutions of the crank and continue around until the micrometer dial reads 141 thousandths, and so on.

Table of Divisions Corresponding to Given Circumferential Distances

This table gives approximate number of divisions and distances apart on circumference, corresponding to a known diameter of work. It is useful in milling-machine work in cutting mills, saws, ratchets, etc.

Dia. of Work	Distance on Circumference														
	1/32″	1/16″	1/8″	3/16″	1/4″	5/16″	3/8″	7/16″	1/2″	9/16″	5/8″	11/16″	3/4″	7/8″	1″
1/4	25	12	6												
5/16	31	16	8												
3/8	38	19	9	6											
7/16	44	22	11	7	5										
1/2	50	25	13	8	6										
5/8	63	31	16	10	8	6									
3/4	75	38	19	13	9	8	6								
7/8	88	44	22	15	11	9	7	6							
1	100	50	25	17	13	10	8	7	6						
1 1/4	126	63	31	21	16	13	10	9	8	7	6				
1 1/2	150	75	38	25	19	15	13	11	10	8	7				
1 3/4	176	88	44	29	22	18	15	13	11	10	9	8	7	6	
2	200	100	50	34	25	20	17	14	12	11	10	9	8	7	6
2 1/4	226	113	56	38	28	23	19	16	14	13	11	10	9	8	7
2 1/2	251	125	63	42	31	25	21	18	16	14	12	11	10	9	8
2 3/4	277	138	69	46	35	28	23	20	17	15	14	13	12	10	9
3	302	151	75	50	38	30	25	22	19	17	15	14	13	11	9
3 1/4	327	163	82	54	41	33	27	23	20	18	16	15	14	12	10
3 1/2	352	176	88	59	44	35	30	25	22	20	18	16	15	13	11
3 3/4	378	189	94	63	47	38	31	27	24	21	19	17	16	14	12
4	402	201	100	67	50	40	34	29	25	22	20	18	17	15	13
4 1/4	428	214	107	71	53	43	36	31	27	24	21	19	18	15	13
4 1/2	454	227	114	76	57	45	38	32	28	25	23	21	19	16	14
4 3/4	478	239	119	79	60	48	40	34	30	27	24	22	20	17	15
5	503	252	126	84	63	50	42	36	31	28	25	23	21	18	16
5 1/4	528	264	132	88	66	53	44	38	33	29	26	24	22	19	16
5 1/2	554	277	138	92	69	55	46	40	35	31	27	25	23	20	17
5 3/4	579	289	145	96	73	58	48	41	36	32	28	26	24	21	18
6	604	302	151	101	76	61	50	44	38	34	30	27	25	22	19

For example: A straddle mill, say, 5 inches in diameter, is to be cut with teeth 7/16 apart. Without a table of this kind the workman will have to go to the trouble of multiplying the diameter by 3.1416 and then divide by 7/16 to find the number of teeth to set up for. In the table, under 7/16 and opposite 5, he can find at once the number of divisions, as 36. Where the table shows an odd number of teeth, one more or less can, of course, be taken if it is important to have even number of teeth.

TABLE FOR INDEXING ANGLES—INDEX PLATES (see explanation on page 191)

Holes	15	16	17	18	19	20	21	23	27	29	31	33	37	39	41	43	47	49	Holes
1	0.0666	0.0625	0.0588	0.0555	0.0526	0.0500	0.0476	0.0435	0.0370	0.0345	0.0323	0.0303	0.0270	0.0256	0.0244	0.0233	0.0213	0.0204	1
2	0.1333	0.1250	0.1176	0.1111	0.1053	0.1000	0.0952	0.0870	0.0741	0.0690	0.0645	0.0606	0.0541	0.0513	0.0488	0.0465	0.0426	0.0408	2
3	0.2000	0.1875	0.1765	0.1666	0.1579	0.1500	0.1429	0.1304	0.1111	0.1034	0.0968	0.0909	0.0811	0.0769	0.0732	0.0698	0.0638	0.0612	3
4	0.2667	0.2500	0.2353	0.2222	0.2105	0.2000	0.1904	0.1739	0.1481	0.1379	0.1290	0.1212	0.1081	0.1026	0.0976	0.0930	0.0851	0.0816	4
5	0.3333	0.3125	0.2941	0.2777	0.2632	0.2500	0.2381	0.2174	0.1852	0.1724	0.1613	0.1515	0.1351	0.1282	0.1220	0.1163	0.1064	0.1020	5
6	0.4000	0.3750	0.3529	0.3333	0.3158	0.3000	0.2857	0.2609	0.2222	0.2069	0.1935	0.1818	0.1622	0.1538	0.1463	0.1395	0.1277	0.1224	6
7	0.4667	0.4375	0.4118	0.3888	0.3684	0.3500	0.3333	0.3043	0.2593	0.2414	0.2258	0.2121	0.1892	0.1795	0.1707	0.1628	0.1489	0.1429	7
8	0.5333	0.5000	0.4706	0.4444	0.4211	0.4000	0.3810	0.3478	0.2963	0.2759	0.2581	0.2424	0.2162	0.2051	0.1951	0.1860	0.1702	0.1633	8
9	0.6000	0.5625	0.5294	0.5000	0.4737	0.4500	0.4286	0.3913	0.3333	0.3103	0.2903	0.2727	0.2432	0.2308	0.2195	0.2093	0.1915	0.1837	9
10	0.6666	0.6250	0.5882	0.5555	0.5263	0.5000	0.4762	0.4348	0.3703	0.3448	0.3226	0.3030	0.2703	0.2564	0.2439	0.2326	0.2128	0.2040	10
11	0.7333	0.6875	0.6471	0.6111	0.5789	0.5500	0.5238	0.4783	0.4074	0.3793	0.3548	0.3333	0.2973	0.2821	0.2683	0.2558	0.2340	0.2245	11
12	0.8000	0.7500	0.7059	0.6666	0.6316	0.6000	0.5714	0.5217	0.4444	0.4138	0.3871	0.3636	0.3243	0.3077	0.2927	0.2791	0.2553	0.2449	12
13	0.8666	0.8125	0.7647	0.7222	0.6842	0.6500	0.6190	0.5652	0.4815	0.4483	0.4194	0.3939	0.3514	0.3333	0.3171	0.3023	0.2766	0.2653	13
14	0.9333	0.8750	0.8230	0.7777	0.7368	0.7000	0.6666	0.6087	0.5185	0.4827	0.4516	0.4242	0.3784	0.3590	0.3415	0.3256	0.2979	0.2857	14
15		0.9375	0.8824	0.8333	0.7895	0.7500	0.7143	0.6522	0.5555	0.5172	0.4839	0.4545	0.4054	0.3846	0.3659	0.3488	0.3191	0.3061	15
16			0.9412	0.8888	0.8421	0.8000	0.7619	0.6957	0.5924	0.5517	0.5161	0.4848	0.4324	0.4103	0.3902	0.3721	0.3404	0.3265	16
17				0.9444	0.8947	0.8500	0.8095	0.7391	0.6296	0.5862	0.5484	0.5151	0.4596	0.4359	0.4146	0.3954	0.3617	0.3469	17
18					0.9474	0.9000	0.8571	0.7826	0.6666	0.6207	0.5806	0.5454	0.4865	0.4615	0.4390	0.4186	0.3830	0.3673	18
19						0.9500	0.9048	0.8261	0.7037	0.6552	0.6129	0.5757	0.5135	0.4872	0.4634	0.4419	0.4043	0.3878	19
20							0.9524	0.8696	0.7407	0.6897	0.6452	0.6060	0.5405	0.5128	0.4878	0.4651	0.4255	0.4082	20
21								0.9130	0.7777	0.7241	0.6774	0.6363	0.5676	0.5385	0.5122	0.4884	0.4468	0.4286	21
22								0.9565	0.8148	0.7586	0.7097	0.6666	0.5946	0.5641	0.5366	0.5116	0.4681	0.4490	22
									0.8519	0.7931	0.7419	0.6969	0.6216	0.5897	0.5610	0.5349	0.4894	0.4694	23
									0.8888	0.8276	0.7742	0.7272	0.6486	0.6154	0.5854	0.5581	0.5106	0.4898	24

TABLE FOR INDEXING ANGLES

The table saves many calculations when obtaining proper index for angles, either in degrees, minutes or seconds, or all three collectively. An example will readily show its application.

The angle to be indexed is one of 31 deg., 17 min., 11 sec. Reducing the angle to seconds = 112,631. One turn of the crank = 9 deg., which reduced to seconds = 32,400.

$$\frac{112{,}631}{32{,}400} = 3.4762 \textit{ turns}$$

We find in the table 0.4762 = $\frac{10}{21}$; thus, three turns and 10 holes on the 21 circle give correct results to four decimal places.

Index Plates	27	29	31	33	37	39	41	43	47	49	Holes
	0.9259	0.8621	0.8065	0.7575	0.6757	0.6410	0.6098	0.5814	0.5319	0.5102	25
	0.9630	0.8966	0.8387	0.7878	0.7027	0.6666	0.6341	0.6047	0.5532	0.5306	26
		0.9310	0.8710	0.8181	0.7297	0.6923	0.6585	0.6279	0.5745	0.5510	27
		0.9655	0.9032	0.8484	0.7568	0.7179	0.6829	0.6512	0.5957	0.5714	28
			0.9355	0.8787	0.7838	0.7436	0.7073	0.6744	0.6170	0.5918	29
			0.9677	0.9090	0.8108	0.7692	0.7317	0.6977	0.6383	0.6122	30
				0.9393	0.8378	0.7949	0.7561	0.7209	0.6596	0.6326	31
				0.9696	0.8647	0.8205	0.7805	0.7442	0.6809	0.6531	32
					0.8919	0.8462	0.8049	0.7674	0.7021	0.6735	33
					0.9189	0.8718	0.8293	0.7907	0.7234	0.6939	34
					0.9459	0.8974	0.8537	0.8140	0.7447	0.7143	35
					0.9730	0.9231	0.8780	0.8372	0.7760	0.7347	36
						0.9487	0.9024	0.8605	0.7872	0.7551	37
						0.9743	0.9268	0.8837	0.8085	0.7755	38
							0.9512	0.9070	0.8298	0.7959	39
							0.9756	0.9302	0.8511	0.8163	40
								0.9535	0.8723	0.8367	41
								0.9768	0.8936	0.8571	42
									0.9149	0.8775	43
									0.9362	0.8980	44
									0.9574	0.9184	45
									0.9787	0.9388	46
										0.9592	47
										0.9796	48

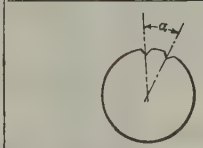


Table of Cutters, Pitches, Gears and Angles for Twist Drills

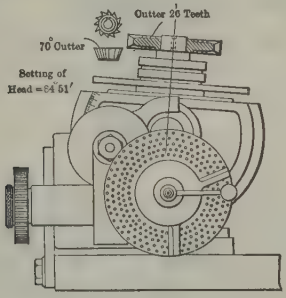
Diameter of Drill in Inches	Thickness of Cutter in Inches	Pitch in Inches	Gear on Worm	First Gear on Stud	Second Gear on Stud	Gear on Screw	Angle of Spiral
1/8	0.08	1.12	24	86	40	100	19° 20′
3/16	0.11	1.67	24	64	32	72	19° 25′
1/4	0.15	1.94	32	64	28	72	21°
5/16	0.19	2.92	24	64	56	72	20°
3/8	0.23	3.24	40	48	28	72	21°
7/16	0.27	3.89	56	48	24	72	20° 10′
1/2	0.31	4.17	40	72	48	64	20° 30′
9/16	0.35	4.86	40	64	56	72	20°
5/8	0.39	5.33	48	40	32	72	20° 12′
11/16	0.44	6.12	56	40	28	64	19° 30′
3/4	0.50	6.48	56	48	40	72	20°
7/8	0.62	7.62	64	48	32	56	19° 50′
1	0.77	8.95	86	48	28	56	19° 20′

Largest Squares that can be Milled on Round Stock

Diam. of Stock	Decimal Equivalent	Size of Square	Nearest Fraction	Diam. of Stock	Decimal Equivalent	Size of Square	Nearest Fraction
1/8	.125	.088	3/32 −	1 1/16	1.5625	1.105	1 7/64 −
3/16	.1875	.133	1/8 +	1 1/8	1.625	1.149	1 5/32 −
1/4	.250	.177	11/64 −	1 1/16	1.6875	1.193	1 3/16 +
5/16	.3125	.221	7/32 +	1 1/4	1.750	1.237	1 1/4 +
3/8	.375	.265	17/64 −	1 3/16	1.8125	1.282	1 9/32 +
7/16	.4375	.309	5/16 −	1 7/16	1.875	1.326	1 5/16 −
1/2	.500	.354	23/64 −	1 5/16	1.9375	1.370	1 3/8 −
9/16	.5625	.398	25/64 +	2	2.000	1.414	1 13/32 +
5/8	.625	.442	7/16 +	2 1/16	2.0625	1.458	1 7/16 +
11/16	.6875	.486	31/64 +	2 1/8	2.125	1.502	1 1/2 +
3/4	.750	.530	33/64 −	2 3/16	2.1875	1.547	1 35/64 −
13/16	.8125	.574	37/64 −	2 1/4	2.250	1.591	1 37/64 −
7/8	.875	.619	5/8 −	2 5/16	2.3125	1.635	1 41/64 −
15/16	.9375	.663	21/32 +	2 3/8	2.375	1.679	1 43/64 +
1	1.000	.707	45/64 +	2 7/16	2.4375	1.723	1 45/64 +
1 1/16	1.0625	.755	3/4 +	2 1/2	2.500	1.768	1 47/64 +
1 1/8	1.125	.795	51/64 −	2 9/16	2.5625	1.813	1 1/16 −
1 3/16	1.1875	.840	27/32 −	2 5/8	2.625	1.856	1 55/64 −
1 1/4	1.250	.884	57/64 −	2 11/16	2.6875	1.900	1 29/32 −
1 5/16	1.3125	.928	59/64 +	2 3/4	2.750	1.944	1 15/16 +
1 3/8	1.375	.972	31/32 +	2 13/16	2.8125	1.989	1 63/64 +
1 7/16	1.4375	1.016	1 1/64 +	2 7/8	2.875	2.033	2 1/32 +
1 1/2	1.500	1.061	1 1/16 −	2 15/16	2.9375	2.077	2 3/64 −
Side of Largest Square = Dia. of Stock × .707				3	3.000	2.121	2 1/8 −

MILLING SIDE TEETH IN MILLING CUTTERS

THE table gives the angle at which to set the dividing head of a miller when milling the side teeth in milling cutters.



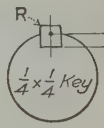
MILLING SIDE TEETH IN MILLING CUTTERS. ANGLE TO SET DIVIDING HEAD

No. of Teeth	ANGLE OF CUTTER USED							
	45°	50°	60°	65°	70°	75°	80°	85°
6				42° 29′	50° 55′	62° 21′	72° 13′	81° 17′
7			43° 36′	54° 13′	62° 50′	70° 22′	77° 13′	83° 42′
8		32° 57′	54° 44′	62° 12′	68° 39′	74° 28′	79° 50′	84° 59′
9	32° 58′	45° 15′	61° 01′	66° 58′	72° 13′	77° 00′	81° 29′	85° 47′
10	43° 24′	52° 26′	65° 12′	70° 12′	74° 40′	78° 46′	82° 38′	86° 21′
12	54° 44′	61° 02′	70° 32	74° 23′	77° 52′	81° 06′	84° 09′	87° 06′
14	61° 12	66° 10′	73° 51′	77° 01′	79° 54′	82° 35′	85° 08′	87° 35′
16	65° 32	69° 40′	76° 10′	78° 52′	81° 20′	83° 37′	85° 49′	87° 55′
18	68° 39′	72° 13′	77° 52′	80° 13′	82° 23′	84° 21′	86° 19′	88° 10′
20	71° 03′	74° 11′	79° 11′	81° 17′	83° 13′	85° 00′	86° 43′	88° 22′
22	72° 55′	75° 44′	80° 14′	82° 08′	83° 52′	85° 29′	87° 02′	88° 31′
24	74° 28′	77° 00′	81° 06′	82° 49′	84° 24′	85° 53°	87° 18′	88° 39′
26	75° 44′	78° 04′	81° 49′	83° 33′	84° 51′	86° 12′	87° 30′	88° 45′
28	76° 49′	78° 58′	82° 26′	83° 53′	85° 14′	86° 29′	87° 42′	88° 51′
30	77° 44′	79° 43′	82° 57′	84° 18′	85° 34′	86° 44′	87° 51′	88° 56′
32	78° 32′	80° 23′	83° 24′	84° 40′	85° 51′	86° 56′	87° 59′	89° 00′
34	79° 14′	80° 59′	83° 48′	85° 00′	86° 06′	87° 08′	88° 07′	89° 04′
36	79° 51′	81° 29′	84° 09′	85° 17′	86° 19′	87° 17′	88° 13′	89° 07′
38	80° 24′	81° 58′	84° 29′	85° 32′	86° 31′	87° 26′	88° 18′	89° 09′
40	80° 53′	82° 22′	84° 45′	85° 46′	86° 42′	87° 34′	88° 24′	89° 12′
42	81° 20′	82° 44′	85° 00′	85° 58′	86° 51′	87° 41′	88° 29′	89° 14′

The table shows the angle to the nearest minute, but as an ordinary dividing head is not graduated to read in minutes, the nearest quarter degree is taken.

MILLING MACHINE ARBOR KEY STANDARDS

Adopted by leading cutter manufacturers in 1925 as basis for Keyways in milling cutters. The Keys are square with a radius on the projecting corners as given in table. Depth is taken from arbor diameter, not from side of Keyway.



Diam. of Arbor	1 in.	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$
Size of Sq. Key	$\frac{1}{4}$ in.	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$
Depth-D	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{13}{32}$	$\frac{13}{32}$	$\frac{1}{2}$
Radius-R	$\frac{3}{64}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{16}$

Center Reamer

DIAMETER OF STRADDLE MILL FOR FLUTING (3 FLUTES)

Size of Reamer	Outside Dia. of Cutter	Size of Reamer	Outside Dia. of Cutter
$\frac{1}{4}$" cut	$2\frac{1}{2}$	$\frac{3}{4}$" cut	$3\frac{1}{2}$
$\frac{3}{4}$" cut	$2\frac{3}{4}$	1" cut	$3\frac{3}{4}$
$\frac{1}{2}$" cut	3	1" cut	4
$\frac{5}{8}$" cut	$3\frac{1}{4}$		

MILLING CUTTER, REAMER AND TAP FLUTES

THE following tables give the number of teeth or flutes suitable for milling in various types of cutters, reamers, taps, etc., and also show the forms of fluting cutters used.

END MILLS

(Dimensions in Inches)

STRAIGHT AND SPIRAL TEETH

Diam. Mill	No. Teeth	Diam. Mill	No. Teeth
$\frac{1}{4}$–$\frac{5}{16}$	5	$\frac{7}{8}$–1 $\frac{1}{16}$	8
$\frac{3}{8}$–$\frac{9}{16}$	6	1 $\frac{1}{8}$–1 $\frac{5}{16}$	9
$\frac{5}{8}$–$\frac{13}{16}$	7	1 $\frac{3}{8}$–1 $\frac{1}{2}$	10

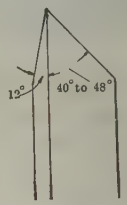
SHELL END MILLS; STRAIGHT OR SPIRAL TEETH		INSERTED TOOTH CUTTERS, P. & W. FORM	
Diam. Mill	No. Teeth	Diam. Cutter	No. Blades
		4	8
		5	9
		6	10
		7	12
1 $\frac{7}{16}$	14	8	13
1 $\frac{1}{2}$–2 $\frac{1}{2}$	16	10	16
2 $\frac{9}{16}$–3	18	12	18

METAL-SLITTING CUTTERS

Diam. Cutter	No. Teeth	Pitch	Diam. Cutter	No. Teeth	Pitch
2 $\frac{3}{4}$	72	$\frac{1}{8}$	2 $\frac{1}{2}$	31	$\frac{1}{4}$
2 $\frac{1}{4}$	60	$\frac{1}{8}$	3	30	$\frac{5}{16}$
1 $\frac{3}{4}$	90		4	34	$\frac{3}{8}$
			5	38	$\frac{13}{32}$
			6	42	$\frac{27}{64}$
			7	48	$\frac{23}{64}$
			8	55	$\frac{25}{64}$

Plain Milling Cutters	
Diam. of Cutter in Inches	No. of Teeth
$2\frac{3}{4}$ – $3\frac{7}{16}$ inclusive	16
$3\frac{1}{2}$ – $4\frac{7}{16}$ inclusive	18
$4\frac{1}{2}$ – $4\frac{15}{16}$ inclusive	20
5 – $5\frac{15}{16}$ inclusive	22
6 – $7\frac{1}{16}$ inclusive	24
8 – $8\frac{1}{16}$ inclusive	26
9 – $9\frac{1}{16}$ inclusive	28
10 – $10\frac{1}{16}$ inclusive	30
11 – $11\frac{1}{16}$ inclusive	32
12 – $12\frac{1}{16}$ inclusive	36

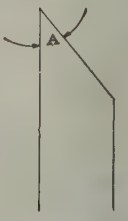
Fluting Cutters



Form of Cutter for Milling Teeth in Plain Milling Cutters.

Plain cutters of $\frac{3}{4}$-inch face and over are generally made with spiral teeth. The 12-degree angle on side of fluting cutter gives ample clearance for cutting spiral grooves with the 12-degree face set on the center line of the work.

Side or Straddle Mills	
Diam. of Cutter in Inches	No. of Teeth
2 – $2\frac{7}{16}$ inclusive	14
$2\frac{1}{2}$ – $2\frac{15}{16}$ inclusive	16
3 – $3\frac{7}{16}$ inclusive	18
$3\frac{1}{2}$ – $3\frac{15}{16}$ inclusive	20
4 – $4\frac{15}{16}$ inclusive	22
5 – $5\frac{15}{16}$ inclusive	24
6 – $6\frac{15}{16}$ inclusive	26
7 – $7\frac{15}{16}$ inclusive	28
8 – $10\frac{15}{16}$ inclusive	30
11 – $12\frac{15}{16}$ inclusive	32



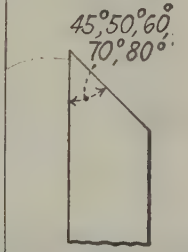
Angular Cutter for Milling Teeth in Straddle Milling Cutters.

When face of side mill is more than $1\frac{3}{8}$ inches, teeth are milled spiral at an angle of 12 degrees and with the same number of teeth as the plain milling cutter.

For milling teeth on periphery of straddle mills use angular cutter with 60-degree angle at A; for milling teeth on sides of cutters use 70-, 75- or 80-degree cutter according to number of teeth in cutter to be milled.

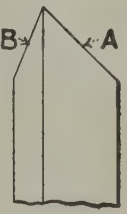
Corner Rounding Cutters

Diam. in Inches	Radius of Circle in Inches	No. of Teet
2	$\frac{1}{16}$	14
2	$\frac{3}{32}$	13
2	$\frac{1}{8}$	13
$2\frac{1}{4}$	$\frac{6}{32}$	12
$2\frac{1}{4}$	$\frac{3}{16}$	12
$2\frac{1}{4}$	$\frac{7}{32}$	11
$2\frac{1}{4}$	$\frac{1}{4}$	11
$2\frac{3}{4}$	$\frac{5}{16}$	10
3	$\frac{3}{8}$	10
$3\frac{1}{4}$	$\frac{7}{16}$	10
$3\frac{1}{4}$	$\frac{1}{2}$	10
$3\frac{1}{2}$	$\frac{9}{16}$	10
$3\frac{1}{2}$	$\frac{5}{8}$	10
$3\frac{3}{4}$	$\frac{11}{16}$	10
$3\frac{3}{4}$	$\frac{3}{4}$	10



Concave and Convex Cutters

Diam. in Inches	Diam. of Circle in Inches	No. of Teeth
2	$\frac{1}{8}$	14
2	$\frac{3}{16}$	13
2	$\frac{1}{4}$	13
$2\frac{1}{4}$	$\frac{5}{16}$	12
$2\frac{1}{4}$	$\frac{3}{8}$	12
$2\frac{1}{4}$	$\frac{7}{16}$	11
$2\frac{1}{4}$	$\frac{1}{2}$	11
$2\frac{3}{4}$	$\frac{5}{8}$	10
3	$\frac{3}{4}$	10
$3\frac{1}{4}$	$\frac{7}{8}$	10
$3\frac{1}{4}$	1	10
4	$1\frac{1}{8}$	10
4	$1\frac{1}{4}$	10
$4\frac{1}{4}$	$1\frac{3}{8}$	10
$4\frac{1}{4}$	$1\frac{1}{2}$	10



ANGULAR CUTTERS

Diam. of Cutter in Inches	No. of Teeth
$2\frac{1}{2}$	16
$2\frac{3}{4}$	18
3	20
$3\frac{1}{4}$	22

DOUBLE ANGLE

Diam. of Cutter in Inches	No. of Teeth
$2\frac{1}{2}$	16
$2\frac{3}{4}$	18
3	22

Cutters for spiral mills are made same diameter as angular cutters and have same number of teeth.

TAPER REAMERS (B. & S. TAPER)

No. of Taper	Flutes
1– 4	6
5– 9	8
10–15	10
16–18	12

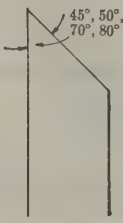
Corner Rounding Cutters

Diam. Cutter in Inches	Rad. Circle	No. Teeth
2	$\frac{1}{16}$–$\frac{1}{8}$	16
$2\frac{1}{4}$	$\frac{5}{32}$–$\frac{1}{4}$	12
$2\frac{3}{4}$–$3\frac{1}{2}$	$\frac{5}{16}$–$\frac{5}{8}$	10
$3\frac{3}{4}$	$\frac{11}{16}$–$\frac{3}{4}$	8

Concave and Convex Cutters

Diam. Cutter in Inches	Diam. Circle in Inches	No. Teeth
2	$\frac{1}{8}$–$\frac{1}{4}$	16
$2\frac{1}{4}$	$\frac{5}{16}$–$\frac{1}{2}$	12
$2\frac{1}{2}$–4	$\frac{9}{16}$–$1\frac{1}{8}$	10

Fluting Cutters



Angular Cutter for Milling Teeth in Corner Rounding, Concave and Convex Cutters.

Angular Cutters

Diam. of Cutter in Inches	No. of Teeth
$2\frac{1}{2}$	20
$2\frac{3}{4}$	20
3	20

Double-Angle Cutters

Diam. of Cutter in Inches	No. of Teeth
$2\frac{1}{2}$–3	20

Cutters for Spiral Mills

Diam. of Cutters in Inches	No. of Teeth
$2\frac{1}{2}$	20
$2\frac{3}{4}$	20
3	20



Cutter for Milling Teeth in Angular Cutters, Double Angle Cutters and Cutters for Spiral Mills. To cut Teeth on side A of this Cutter use 60° Cutter. To cut side B use 70°–75° Cutter.

Hand Taps

Diam. of Tap in Inches	No. Flutes
$\frac{3}{16}$ to $1\frac{3}{4}$	4
$1\frac{7}{8}$ to $2\frac{3}{4}$	6
3 to 4	8
3 to 4 mm.	3
5 to 44 mm.	4
46 to 50 mm.	6

Machine Screw Taps

Diam. of Tap in Inches	No. Flutes
No. 1 to 7	3
No. 8 to 30	4

Tapper Taps

Diam. of Tap in Inches	No. Flutes
$\frac{1}{4}$–$\frac{5}{8}$	3
$\frac{11}{16}$–1 $\frac{15}{16}$	4
2–$2\frac{1}{4}$	6

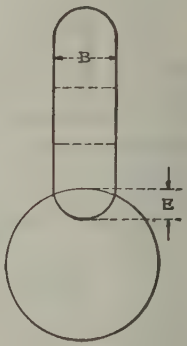
Machine or Nut Taps

Diam. of Tap in Inches	No. Flutes
$\frac{3}{16}$–1 $\frac{7}{8}$	4
1 $\frac{15}{16}$–2 $\frac{5}{16}$	5
$2\frac{3}{8}$–3 $\frac{3}{16}$	6
3 $\frac{1}{4}$–4	7

Screw-Machine Taps

Diam. of Tap in Inches	No. Flutes
$\frac{1}{4}$ to 1 $\frac{1}{2}$	4
1 $\frac{9}{16}$ to 2	6

Tap-Fluting Cutter



With
3 Flutes in Tap, $B = \frac{3}{4}$ Dia. Tap
4 Flutes in Tap, $B = \frac{1}{2}$ Dia. Tap
5 Flutes in Tap, $B = \frac{13}{32}$ Dia. Tap
6 Flutes in Tap, $B = \frac{11}{32}$ Dia. Tap
7 Flutes in Tap, $B = \frac{9}{32}$ Dia. Tap
8 Flutes in Tap, $B = \frac{1}{4}$ Dia. Tap

With
3 Flutes in Tap, $E = \frac{9}{32}$ Dia. Tap
4 Flutes in Tap, $E = \frac{1}{4}$ Dia. Tap
5 Flutes in Tap, $E = \frac{13}{64}$ Dia. Tap
6 Flutes in Tap, $E = \frac{11}{64}$ Dia. Tap
7 Flutes in Tap, $E = \frac{5}{32}$ Dia. Tap
8 Flutes in Tap, $E = \frac{9}{64}$ Dia. Tap

In milling taps with the convex cutter the cutter must be central with the tap.

(Dimensions in Inches)

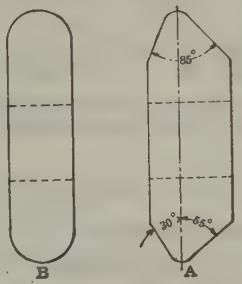
Taper Pipe Taps

Diam. of Tap	No. of Flutes
$\frac{1}{8}$– $\frac{1}{2}$	4
$\frac{3}{4}$	5
1 –1$\frac{1}{2}$	5
2	7
2$\frac{1}{2}$	8
3	9
3$\frac{1}{2}$–4	11

Straight Pipe Taps

Diam. of Tap	No. of Flutes
$\frac{1}{4}$– $\frac{1}{2}$	4
$\frac{3}{4}$–1$\frac{1}{4}$	5
1$\frac{1}{2}$	5
2	7
2$\frac{1}{2}$	8
3	9
3$\frac{1}{2}$	10

Tap Fluting Cutters



Cutter *A* is a regular tap fluting cutter that may be used if preferred for fluting any kind of tap in place of convex cutter *B*.

Pipe Hobs

Diam. Hob	No. Flutes	Diam. Hob	No. Flutes	Diam. Hob	No. Flutes
$\frac{1}{8}$	5	1	12	2$\frac{1}{2}$	24
$\frac{1}{4}$	6	1$\frac{1}{4}$	14	3	28
$\frac{3}{8}$	8	1$\frac{1}{2}$	16	3$\frac{1}{2}$	34
$\frac{1}{2}$	8	2	18	4	38
$\frac{3}{4}$	10			4$\frac{1}{2}$	46

Sellers Hobs

Diam. Hobs	No. Flutes	Diam. Hobs	No. Flutes
$\frac{1}{4}$ – $\frac{3}{8}$	6	1$\frac{1}{2}$	12
$\frac{7}{16}$ – $\frac{5}{8}$	7	1$\frac{5}{8}$–1$\frac{3}{4}$	13
$\frac{11}{16}$ – $\frac{7}{8}$	8	1$\frac{7}{8}$–2$\frac{1}{8}$	14
$\frac{15}{16}$	9	2$\frac{1}{4}$	15
1 –1$\frac{1}{8}$	10	2$\frac{3}{8}$	16
1$\frac{1}{4}$ –1$\frac{3}{8}$	11	2$\frac{1}{2}$	18

Hob Taps

Diam. Hobs	No. Flutes
$\frac{1}{4}$ – $\frac{27}{64}$	6
$\frac{7}{16}$ – $\frac{47}{64}$	7
$\frac{11}{16}$ – $\frac{53}{64}$	8
$\frac{15}{16}$ – $\frac{63}{64}$	9
1 –1$\frac{15}{64}$	10
1$\frac{1}{4}$ –1$\frac{31}{64}$	11
1$\frac{1}{2}$ –1$\frac{49}{64}$	12
1$\frac{5}{8}$ –1$\frac{27}{32}$	13
1$\frac{7}{8}$ –2	14

Hob Fluting Cutter



In fluting hobs leave land $\frac{3}{16}$ inch wide on top.

Shell Reamers
(Dimensions in Inches)

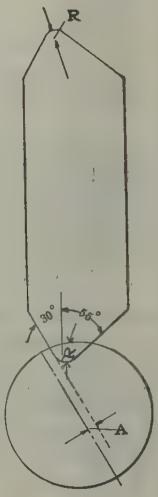
Diam. of Reamer	No. of Flutes	Diam. of Reamer	No. of Flutes	Diam. of Reamer	No. of Flutes
$\frac{1}{4}-\frac{11}{32}$	6	$\frac{5}{8}-1\frac{23}{32}$	10	$2\frac{3}{16}-2\frac{15}{32}$	14
$\frac{3}{8}-\frac{19}{32}$	8	$1\frac{3}{4}-2\frac{5}{32}$	12	$2\frac{1}{2}-4$	16

Taper of hole in shell reamers is $\frac{1}{8}$ inch per foot.

Cutters for Fluting Reamers
(Dimensions in Inches)

Diam. of Reamer	R = Radius of Corner	Diam. of Reamer	R = Radius of Corner
$\frac{1}{8}-\frac{3}{16}$	0	$1\frac{1}{8}-1\frac{1}{2}$	$\frac{1}{16}$
$\frac{1}{4}-\frac{3}{8}$	$\frac{1}{64}$	$1\frac{9}{16}-2\frac{1}{4}$	$\frac{5}{64}$
$\frac{1}{2}-\frac{5}{8}$	$\frac{1}{32}$	$2\frac{5}{16}-3$	$\frac{3}{16}$
$\frac{3}{4}-1$	$\frac{3}{64}$		

Diam. of Reamer	A = Am't Cutting Edge is Ahead of Center	Diam. of Reamer	A = Am't Cutting Edge is Ahead of Center
$\frac{1}{4}$	0.011	$1\frac{1}{2}$	0.006
$\frac{3}{8}$	0.016	$1\frac{3}{4}$	0.076
$\frac{1}{2}$	0.022	2	c.087
$\frac{5}{8}$	0.027	$2\frac{1}{4}$	0.098
$\frac{3}{4}$	0.033	$2\frac{1}{2}$	0.109
$\frac{7}{8}$	0.038	$2\frac{3}{4}$	0.120
1	0.044	3	0.131
$1\frac{1}{4}$	0.055		



The type of cutter shown may be used for all classes of reamers except rose reamers.

Brown & Sharpe Standards for Milling Cutters

END MILLS—STANDARD

Straight Teeth		Spiral Teeth	
Diam. in Inches	No. of Teeth	Diam. in Inches	No. of Teeth
$\frac{1}{4}$–$\frac{13}{16}$	6	$\frac{1}{4}$–$\frac{13}{16}$	6
$\frac{7}{8}$–$1\frac{1}{2}$	8	$\frac{7}{8}$–$1\frac{11}{16}$	8
		$1\frac{3}{4}$–2	10

END MILLS—COARSE TOOTH

Spiral Teeth Only

Diam. in Inches	No. of Teeth
Up to $\frac{3}{4}$	4
$\frac{13}{16}$–$1\frac{1}{2}$	6
$1\frac{9}{16}$–2	8

STRAIGHT SHANK END MILLS

Diam. in Inches	No. of Teeth
Up to $\frac{11}{32}$ (straight teeth)	6
$\frac{3}{8}$ to $\frac{3}{4}$ (spiral teeth)	6

SHELL END MILLS—REGULAR

Straight or Spiral Teeth

Diam. in Inches	No. of Teeth
$1\frac{1}{4}$–$1\frac{5}{8}$ inclusive	8
$1\frac{11}{16}$–$2\frac{1}{16}$ inclusive	10
$2\frac{1}{8}$–$2\frac{11}{16}$ inclusive	12
$2\frac{3}{4}$–3 inclusive	14

SHELL END MILLS—COARSE TOOTH

Diam. in Inches	No. of Teeth
$2\frac{1}{2}$–$3\frac{1}{2}$	8
$3\frac{1}{2}$–5	10
5 –6	12

Metal-Slitting Saws

Thickness, $\frac{1}{32}$, $\frac{3}{64}$, $\frac{1}{16}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{5}{32}$ and $\frac{3}{16}$

Diam. in Inches	No. of Teeth	Diam. in Inches	No. of Teeth	Diam. in Inches	No. of Teeth
2 –$2\frac{7}{16}$	24	4–$4\frac{15}{16}$	36	7–$7\frac{15}{16}$	44
$2\frac{1}{2}$–$2\frac{15}{16}$	28	5–$5\frac{15}{16}$	40	8–$8\frac{15}{16}$	46
3 –$3\frac{15}{16}$	30	6–$6\frac{15}{16}$	42		



ROSE CHUCKING REAMERS

Diam. of Reamer in Inches	No. of End Cuts	No. of Flutes	Diam. of Reamer in Inches	No. of End Cuts	No. of Flutes
1/8– 7/16	6	6	1 3/4–2 3/16	12	12
1/2–1 1/4	8	8	2 1/4–2 3/4	14	14
1 5/16–1 11/16	10	10	2 13/16–3	16	16

NUMBER OF END CUTS SAME AS NUMBER OF FLUTES
TAPER REAMERS

MORSE TAPER		B. & S. TAPER		JARNO TAPER	
No. of Taper	No. of Flutes	No. of Taper	No. of Flutes	No. of Taper	No. of Flutes
0–1	6	1–6	6		
2–4	8	7–11	8	2–5	6
5	10	12–14	10	6–12	8
6	14	15–18	14	13–17	10
7	16			18–20	12

TAPER PIN REAMERS		LOCOMOTIVE TAPER REAMERS	
No. of Reamer	No. of Flutes	Diam. of Reamer in Inches	No. of Flutes
0000–00	6	1/4–1 1/4	6
0– 5	5	1 5/16–1 11/16	8
6– 8	6	1 3/4–2	10
9–10	7		
11–13	8		
14	10		

Sizes of Screw-slotting Cutters

Screw-slotting cutters are used for slotting the heads of screws and for various operations where a shallow slot is required.

The cutters are not ground on the sides.

Screw-slotting cutters Nos. 5 to 14 gage have a standard square keyway; Nos. 15 to 34 gage have no keyway.

Thickness of Cutter, American Wire Gage	Thickness of Cutter in Decimals	Diam. of Cutter in Inches	Number of Teeth	Carbon Steel, Size Hole in Inches	High-speed Steel, Size Hole in Inches
5	0.182	$2\frac{3}{4}$	72	1	
6	0.162	$2\frac{3}{4}$	72	1	1
7	0.144	$2\frac{3}{4}$	72	1	1
8	0.128	$2\frac{3}{4}$	72	$\frac{3}{8}$, 1	1
9	0.114	$2\frac{3}{4}$	72	$\frac{3}{4}$, 1	1
10	0.102	$2\frac{3}{4}$	72	$\frac{3}{4}$, 1	1
11	0.091	$2\frac{3}{4}$	72	$\frac{3}{4}$, 1	1
12	0.081	$2\frac{3}{4}$	72	$\frac{3}{4}$, 1	1
13	0.072	$2\frac{3}{4}$	72	$\frac{3}{4}$, 1	1
14	0.064	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	1
15	0.057	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	1
16	0.051	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	1
17	0.045	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	1
18	0.040	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	1
19	0.035	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	1
20	0.032	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	1
21	0.028	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	1
22	0.025	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	1
23	0.023	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	1
24	0.020	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	1
25	0.018	$2\frac{3}{4}$	72	$\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1	
26	0.016	$2\frac{3}{4}$	72	$\frac{3}{4}$, 1	
27	0.014	$2\frac{3}{4}$	72	$\frac{3}{4}$, 1	
28	0.012	$2\frac{3}{4}$	72	$\frac{3}{4}$, 1	
30	0.010	$2\frac{3}{4}$	72	$\frac{3}{4}$, 1	
32	0.008	$2\frac{3}{4}$	72	$\frac{3}{4}$, 1	
34	0.006	$2\frac{3}{4}$	72	$\frac{3}{4}$, 1	
10	0.102	$2\frac{1}{4}$	60	$\frac{5}{8}$	
11	0.091	$2\frac{1}{4}$	60	$\frac{5}{8}$	
12	0.081	$2\frac{1}{4}$	60	$\frac{5}{8}$	
13	0.072	$2\frac{1}{4}$	60	$\frac{5}{8}$	
14	0.064	$2\frac{1}{4}$	60	$\frac{5}{8}$	
15	0.057	$2\frac{1}{4}$	60	$\frac{5}{8}$	
16	0.051	$2\frac{1}{4}$	60	$\frac{5}{8}$	
17	0.045	$2\frac{1}{4}$	60	$\frac{5}{8}$	
18	0.040	$2\frac{1}{4}$	60	$\frac{5}{8}$	
19	0.035	$2\frac{1}{4}$	60	$\frac{5}{8}$	
20	0.032	$2\frac{1}{4}$	60	$\frac{5}{8}$	

$\frac{1}{8}$ Pitch

Thickness of Cutter American Wire Gage	Thickness of Cutter in Decimals	Diameter of Cutter in Inches	Size of Hole in Inches	Number of Teeth
21	0.028	$2\frac{1}{4}$	$\frac{5}{8}$	60
22	0.025	$2\frac{1}{4}$	$\frac{5}{8}$	60
23	0.023	$2\frac{1}{4}$	$\frac{5}{8}$	60
24	0.020	$2\frac{1}{4}$	$\frac{5}{8}$	60
25	0.018	$2\frac{1}{4}$	$\frac{5}{8}$	60
26	0.016	$2\frac{1}{4}$	$\frac{5}{8}$	60
27	0.014	$2\frac{1}{4}$	$\frac{5}{8}$	60
28	0.012	$2\frac{1}{4}$	$\frac{5}{8}$	60
30	0.010	$2\frac{1}{4}$	$\frac{5}{8}$	60
32	0.008	$2\frac{1}{4}$	$\frac{5}{8}$	60
34	0.006	$2\frac{1}{4}$	$\frac{5}{8}$	60
14	0.064	$1\frac{3}{4}$	$\frac{5}{8}$	90
15	0.057	$1\frac{3}{4}$	$\frac{5}{8}$	90
16	0.051	$1\frac{3}{4}$	$\frac{5}{8}$	90
17	0.045	$1\frac{3}{4}$	$\frac{5}{8}$	90
18	0.040	$1\frac{3}{4}$	$\frac{5}{8}$	90
19	0.035	$1\frac{3}{4}$	$\frac{5}{8}$	90
20	0.032	$1\frac{3}{4}$	$\frac{5}{8}$	90
21	0.028	$1\frac{3}{4}$	$\frac{5}{8}$	90
22	0.025	$1\frac{3}{4}$	$\frac{5}{8}$	90
23	0.023	$1\frac{3}{4}$	$\frac{5}{8}$	90
24	0.020	$1\frac{3}{4}$	$\frac{1}{2}$, $\frac{5}{8}$	90
25	0.018	$1\frac{3}{4}$	$\frac{1}{2}$, $\frac{5}{8}$	90
26	0.016	$1\frac{3}{4}$	$\frac{1}{2}$, $\frac{5}{8}$	90
27	0.014	$1\frac{3}{4}$	$\frac{1}{2}$, $\frac{5}{8}$	90
28	0.012	$1\frac{3}{4}$	$\frac{1}{2}$, $\frac{5}{8}$	90
30	0.010	$1\frac{3}{4}$	$\frac{1}{2}$, $\frac{5}{8}$	90
32	0.008	$1\frac{3}{4}$	$\frac{1}{2}$, $\frac{5}{8}$	90
34	0.006	$1\frac{3}{4}$	$\frac{1}{2}$, $\frac{5}{8}$	90

$\frac{1}{8}$ Pitch

$\frac{1}{16}$ Pitch

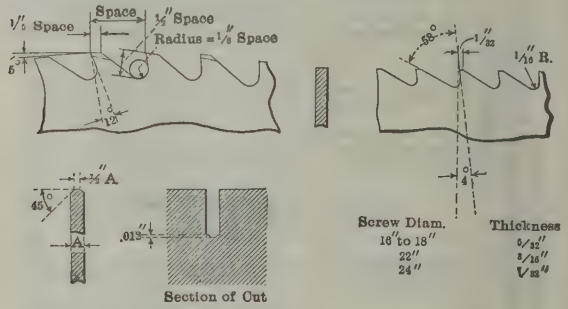
CUTTING SPEEDS FOR COLD SAW CUTTING-OFF MACHINES

The table on page 313 shows the practice of the Brown & Sharpe Mfg. Co. The semi-high speed stell is used for soft steel but high speed is recommended for cutting tool steel. A good lard cutting oil is preferred though it can be dark colored and more impure than for screw machines.

TABLE OF CUTTING SPEEDS FOR COLD SAW CUTTING-OFF MACHINES

Diameter of Stock	Diameter of Saw	Machinery and Soft Steel				Tool Steel				High-speed Tool Steel			
		Number of Teeth in Saw	Cutting Speed of Saw, Ft. per Min.	Feed of Saw Inches per Min.	Revolutions of Saw per Min.	Approx. Min. to Cut Off One Piece	Number of Teeth in Saw	Cutting Speed of Saw, Ft. per Min.	Feed of Saw, Inches per Min.	Revolutions of Saw per Min.	Approx. Min. to Cut Off One Piece	Number of Teeth in Saw	Cutting Speed of Saw, Ft. per Min.	Feed of Saw, Inches per Min.	Revolutions of Saw, per Min.	Approx. Min. to Cut Off One Piece
2	16	76	50	0.88	11.93	2¼	108	70	0.666	16.71	3	108	50	0.250	11.93	8
2½	16	76	50	0.833	11.93	3	108	70	0.555	16.71	4½	108	50	0.230	11.93	10
3	16	76	50	0.750	11.93	4	108	70	0.500	16.71	6	108	50	0.230	11.93	12
3½	18	76	50	0.70	11.93	5	108	70	0.466	16.71	7½	108	50	0.225	11.93	15¾
4	18	76	50	0.66	10.61	6	108	70	0.444	14.85	9	108	50	0.210	10.61	19
4½	18	76	50	0.642	10.61	7	108	70	0.409	14.85	11	108	50	0.195	10.61	23
5	18	76	50	0.588	10.61	8½	108	70	0.384	14.85	13	108	50	0.178	10.61	28
5½	18	76	50	0.55	10.61	10	108	70	0.366	14.85	15	108	50	0.166	10.61	33
6	22	86	50	0.50	8.68	12	120	70	0.333	12.15	18	120	50	0.153	8.68	39
6½	22	86	50	0.464	8.68	14	120	70	0.309	12.15	21	120	50	0.138	8.68	47
7	24	86	50	0.411	7.95	17	120	70	0.280	11.14	25	120	50	0.136	7.95	55
7½	24	86	50	0.357	7.95	21	120	70	0.250	11.14	30	120	50	0.116	7.95	64
8	24	86	50	0.307	7.95	26	120	70	0.228	11.14	35	120	50	0.108	7.95	74

The experience of this company has led to the adoption of the saw tooth shown herewith. This allows a slower speed and coarser feed than finer teeth, and cuts stock more easily and quickly.



Newton (Consolidated) Works recommend a high speed and light feed for stell low in carbon and manganese to keep the chip thin as possible. Up to 35-point carbon use 60 to 65 feet per minute for solid blades. From 35 to 50-point carbon, 55 to 60 feet per minute and less feed. Above 50-point carbon use inserted tooth saws. With inserted tooth saws speeds can be from 50 to 80 feet per minute on 50 to 70-point carbon, but only on heavy, rigid machines. For cutting sprues in steel foundries a solid tooth saw with a speed of 55 feet per minute and a feed of $\frac{1}{4}$ to $\frac{3}{8}$ inch per minute is recommended.

The work should be flooded at all times with any good cutting compound which does not rust.

Hack Saws (Starret)

Hack saws for use in hand frames vary from 6 to 12 inches in length and from 18 to 32 teeth per inch in most cases. They are usually $\frac{7}{16}$ or $\frac{1}{2}$ inch wide and 0.025 inch thick. Saws for use in power machines are made from 10 to 24 inches long and with from 8 to 24 teeth per inch. They are from $\frac{5}{8}$ to 1 inch wide and from 0.030 to 0.065 inch thick. Some have stiff backs, while others are made flexible.

For general use in hand frames, makers recommend 18 teeth per inch. For tubing and thin metals, 24 to 32 teeth per inch. Saws for use in power machines vary in the same way and with the speed and size of machine.

Power-machine saws should run about 50 strokes per minute dry or from 65 to 100 strokes with compound. Too much weight dulls a new saw quickly. Use fine saws for pipes, tubes, thin metal, brass, copper or very hard steel.

Saw length usually means distance between holes.

This table helps to select the proper blade for practically all hack-saw work.

Hack-saw Blade Chart

HACK-SAW BLADES

Type	No. Teeth	Wide in Inches	Thick in Inches	Length in Inches	Material to Cut
Hand	14	$\frac{5}{8}$	0.028	8–13	Cast iron, cold rolled steel, soft steel, bronze, aluminum, hard rubber, fiber paper
	16	$\frac{5}{16}$	0.025	12–14	Heavier material than 18 tooth
	18	$\frac{1}{2}$	0.025	8–13	Tool steel, hard metals, light structural shapes, general purpose
	24	$\frac{1}{2}$	0.025	8–11	Tubing, wrought pipe, C.B., copper, draw rod el. casing, X light structural metal trim, 16–18 g. sheet metal
	32	$\frac{1}{2}$	0.025	8–11	Thin copper and brass tubing, sheet metal, 19 and thin metal trim
Power	4	$1\frac{1}{2}$	0.065	17–18	Large size cold rolled steel and shaft
D	6	$1\frac{1}{8}$	0.048	12–24	Cold rolled steel or shafting over 2 inches
D	8	1	0.048	12–24	Cold rolled steel or shafting over 2 inches
D	8	1	0.065	17–32	Cold rolled steel or shafting under 2 inches
D	8	$1\frac{1}{4}$	0.048	12–24	Cold rolled steel or shafting under 2 inches
C	10	$\frac{3}{4}$	0.048	10–17	Cast iron, machine steel, bronze
C	10	1	0.065	14–32	Cast iron, machine steel, bronze
C	10	1	0.048	10–24	Cold rolled steel and shaft
D	10	$1\frac{1}{4}$	0.048	17–18	Cold rolled steel and shaft over 2 inches
D	10	$1\frac{1}{2}$	0.065	18–30	Cold rolled steel and shaft under 2 inches
C	12	$\frac{3}{4}$	0.048	10–18	Cast iron machine steel, bronze
C	12	1	0.048	14–18	Cast iron machine steel, bronze
D	12	1	0.048	10–24	Tool steel and hard metals
B	14	$\frac{5}{8}$	0.028	10–18	Cutting stock 2 inches under, tool steel, wrought iron, cast iron, copper and brass solid
B	14	$\frac{3}{4}$	0.032	12–20	Cutting stock 2 inches over, tool steel, wrought iron, cast iron, copper and brass solid
B	14	$\frac{3}{4}$	0.042	12–14	Cutting stock 2 inches under, tool steel, wrought iron, cast iron, copper and brass solid
B	14	$\frac{3}{4}$	0.065	17–18	Pipe and structural shapes
D	C	14	1	0.042	12–17	Tool steel and hard metals
B	18	$\frac{3}{4}$	0.028	12–14	Iron pipe, copper and brass tube, not under 16 g. or over 2 inches diameter
B	18	$\frac{3}{4}$	0.032	12–14	Iron pipe, copper and brass tube, not under 16 g. or more than 2 inches diameter
B	18	1	0.048	14–18	Structural shapes, brass and copper tube

B = Light gravity feed—slow speed C = Regular gravity feed machine D = Heavy gravity or positive feed machine

TURNING AND BORING

THE accompanying table is a ready means of figuring machine time on turned, bored or faced work.

The ordinary method employed is to ascertain the number of feet in the circumference of the piece by multiplying the diameter in inches by 3.1416 and dividing by 12. The next step consists of dividing the length by the feed used, which gives the entire number of revolutions the piece must make.

CONSTANTS FOR CUTTING TIME, IN MINUTES

FEED IN INCHES	CUTTING SPEED						
Two Cuts at	15 Feet	18 Feet	20 Feet	25 Feet	30 Feet	35 Feet	40 Feet
1–64 1–32	1.676	1.396	1.257	1.005	0.8378	0.7181	0.6281
1–32 1–16	0.8378	0.6981	0.6283	0.5027	0.4189	0.3590	0.3141
1–16 1– 8	0.4189	0.3491	0.3142	0.2513	0.2094	0.1795	0.1570
1– 8 1– 4	0.2094	0.1745	0.1571	0.1257	0.1047	0.0898	0.0785
One Cut at							
1–64	1.117	0.9308	0.8378	0.6702	0.5585	0.4787	0.4189
1–32	0.5585	0.4654	0.4189	0.3351	0.2793	0.2304	0.2094
1–16	0.2702	0.2327	0.2094	0.1676	0.1396	0.1107	0.1047
1– 8	0.1396	0.1164	0.1047	0.0838	0.0698	0.0508	0.0524
1– 4	0.0698	0.0582	0.0524	0.0419	0.0349	0.0299	0.0262
Two Cuts at	45 Feet	50 Feet	60 Feet	70 Feet	80 Feet	90 Feet	100 Feet
1–64 1–32	0.5581	0.5027	0.4189	0.3590	0.3142	0.2703	0.2513
1–32 1–16	0.2703	0.2513	0.2094	0.1795	0.1571	0.1396	0.1257
1–16 1– 8	0.1396	0.1257	0.1047	0.0898	0.0785	0.0698	0.0628
1– 8 1– 4	0.0698	0.0683	0.0524	0.0449	0.0393	0.0349	0.0314
One Cut at							
1–64	0.3723	0.3351	0.2793	0.2394	0.2094	0.1852	0.1676
1–32	0.1862	0.1676	0.1396	0.1197	0.1047	0.0931	0.0838
1–16	0.0931	0.0838	0.0698	0.0598	0.0524	0.0465	0.0419
1– 8	0.0465	0.0419	0.0349	0.0299	0.0262	0.0233	0.0209
1– 4	0.0233	0.0209	0.0175	0.0150	0.0131	0.0116	0.0105

Having the circumference in feet and the number of revolutions, it is necessary to multiply them to find the entire number of feet traveled. Dividing this result by the speed of cut in feet per minute will give the actual cutting time in minutes.

The figuring is not complicated in any way, but it has the disadvantage of taking too much time. It can be resolved into the following formula:

$$\frac{\textit{Diameter} \times 3.1416 \times \textit{length in inches}}{12 \times \textit{speed} \times \textit{feed in inches}} = \textit{Time in minutes.}$$

The known factors in the case can be resolved into a constant which is directly dependent on the feed and speed; hence, a table covering a wide range of speeds and feeds is necessary for their proper use.

One part of the table gives constants for two cuts at $\frac{1}{64}$-inch and $\frac{1}{32}$-inch feed, up to $\frac{1}{8}$-inch and $\frac{1}{4}$-inch feed, at any speed from 15 feet to 100 feet per minute. The rest of the table gives constants for one cut at $\frac{1}{64}$-inch up to and including $\frac{1}{4}$-inch feed, also at any speed from 15 feet to 100 feet per minute.

A typical computation is as follows:

A piece 4 inches in diameter, 10 inches long, is turned with two cuts at $\frac{1}{16}$-inch and $\frac{1}{32}$-inch feed, each with a cutting speed of 20 feet per minute. Diameter $\times$ length in inches $\times$ constant = time in minutes. $4 \times 10 \times 0.6283 = 26$ minutes.

If, for the purpose of accuracy it is thought advisable, in connection with these two cuts, to run another cut over, the constant 0.6283 is added to a constant for the third feed used. If this feed is $\frac{1}{64}$-inch, then we have $0.6283 + 0.8378 = 1.4661$, the constant for three cuts, one of $\frac{1}{16}$-inch, one of $\frac{1}{32}$-inch, and one of $\frac{1}{64}$-inch feed.

Table Has Wide Applications

There is hardly a combination of feeds and speeds that it is not possible to secure by inspection from the table. By interpolation an added number can be secured.

The table can be adapted, on account of its wide range, to the known individual performance of any lathe or boring mill in the shop. No slide rule or any special operations are necessary to secure the desired results, merely a knowledge of multiplication.

For flange facing it is possible to use the table with the same ease as for boring and turning by figuring on the main diameter.

Rotary Cutting Speeds

An easy method of calculating the cutting speed of a lathe tool or milling cutter is to divide the number of revolutions by 4 and multiply by the diameter in *inches*. This gives the cutting speed in *feet* per minute. Dividing 3.1416 by 12 gives .262 and .25 is very close after allowing for belt slip.

Let D = diam. of work, cutter or boring bar.
N = revolutions per minute.
C = cutting speed in feet per minute.

$$C = D \times \frac{N}{4}. \qquad N = \frac{4 \times C}{D}. \qquad D = \frac{4 \times C}{N}.$$

Figuring Turning Speeds

A short-cut rule for quick mental calculation of turning speeds on a lathe or boring mill is: Multiply one-half the revolutions (per minute) by half the diameter (in inches). Add 1 for every 25 in the product. The result is the cutting speed in feet per minute.

Example: What is the cutting speed on a 1½-inch diameter at 400 revolutions per minute?

Solution: $200 \times \frac{3}{4} = 150$; $150 \div 25 = 6$; $150 + 6 = 156$ feet per minute.

Frequently the following statement of the same formula is more convenient, as it avoids dividing the diameter, which sometimes makes a troublesome fraction: Multiply one-quarter the revolutions (per minute) by the diameter (in inches). Add 1 for every 25 in the product. The result is the cutting speed in feet per minute.

Example: What is the cutting speed on a 1⅛-inch diameter at 440 feet per minute?

Solution: $110 \times \frac{9}{8} = 124$; $124 \div 25 = 5$; $124 + 5 = 129$ feet per minute.

To see how closely this "rule of thumb" formula approximates the theoretical formula in accuracy, reduce both to similar terms in the latter example:

Practical formula: $\frac{1}{4} \times 440 \times \frac{9}{8} \times 1\frac{1}{25}$, or 440 (revolutions) $\times \frac{9}{8}$ (diameter) $\times$ 0.260.

Theoretical formula: $3.1416 \times 440 \times \frac{9}{8} \times \frac{1}{12}$, or 440 (revolutions) $\times \frac{9}{8}$ (diameter) $\times$ 0.262.

This comparison shows that, when both formulas are reduced to similar terms, the discrepancy between the "constants" is only the difference between 0.260 and 0.262. This difference represents the amount of error, which is usually so much less than the error in roughly measuring the diameter or the revolutions per minute that it is negligible. Tables on pages 319 to 323 will save time.

Lathe Tool Tests

In testing steels for lathe and similar tools it has become customary to use standard material, speeds, feeds and depth of cut. In some cases tools are run until they break down, in others they are passed if they stand up for a specified time. A 20-point carbon steel is often selected and cuts $\frac{1}{4}$ inch deep with $\frac{1}{16}$ to $\frac{1}{8}$ inch feed at cutting speeds of from 60 to 90 feet per minute.

The U. S. Navy Department specifies that a $\frac{7}{8}$-inch lathe tool shall stand up for 20 minutes with a $\frac{3}{16}$-inch cut and $\frac{1}{16}$-inch feed at 60 feet per minute without regrinding; the material must be at least 80,000-lb. tensile, and 50,000-lb. elastic limit with a 25 per cent. elongation in 2 inches. The steel is annealed before the test.

Time Required for Tool to Travel One Inch When Feed is 1–100 Inch per Revolution

Dia. Inches	Surface Speed per Minute													
	20		25		30		35		40		45		50		60	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
¼	0	20	0	16	0	13	0	11	0	10	0	9	0	8	0	7
5/16	0	25	0	20	0	17	0	14	0	13	0	11	0	10	0	9
⅜	0	29	0	23	0	19	0	17	0	15	0	13	0	12	0	10
7/16	0	34	0	27	0	23	0	19	0	17	0	15	0	14	0	12
½	0	39	0	31	0	26	0	22	0	20	0	17	0	16	0	13
9/16	0	44	0	35	0	29	0	25	0	22	0	19	0	18	0	15
⅝	0	49	0	39	0	32	0	28	0	25	0	22	0	20	0	16
11/16	0	54	0	43	0	36	0	31	0	27	0	24	0	22	0	18
¾	0	59	0	47	0	39	0	34	0	30	0	26	0	24	0	20
13/16	1	4	0	51	0	42	0	36	0	32	0	28	0	26	0	21
⅞	1	9	0	55	0	46	0	39	0	35	0	30	0	28	0	23
15/16	1	14	0	59	0	49	0	42	0	37	0	33	0	30	0	25
1	1	19	1	3	0	52	0	52	0	40	0	35	0	32	0	26
1⅛	1	28	1	10	0	58	0	49	0	44	0	39	0	35	0	29
1¼	1	38	1	18	1	5	0	56	0	49	0	43	0	39	0	33
1⅜	1	48	1	26	1	11	1	2	0	54	0	48	0	43	0	36
1½	1	58	1	34	1	18	1	7	0	59	0	52	0	47	0	39
1⅝	2	8	1	42	1	24	1	13	1	4	0	56	0	51	0	42
1¾	2	18	1	50	1	31	1	19	1	9	1	1	0	55	0	46
1⅞	2	27	1	58	1	37	1	24	1	14	1	5	0	59	0	49
2	2	37	2	6	1	44	1	29	1	19	1	9	1	3	0	52
2⅛	2	46	2	13	1	50	1	34	1	23	1	13	1	6	0	55
2¼	2	56	2	21	1	56	1	40	1	28	1	17	1	11	0	58
2⅜	3	6	2	29	2	3	1	46	1	33	1	22	1	15	1	2
2½	3	16	2	37	2	9	1	52	1	38	1	26	1	19	1	5
2⅝	3	37	2	54	2	23	2	4	1	49	1	35	1	27	1	12
3	3	56	3	9	2	36	2	15	1	58	1	44	1	34	1	18
3¼	4	16	3	25	2	49	2	26	2	8	1	53	1	42	1	25
3½	4	35	3	40	3	2	2	37	2	18	2	1	1	50	1	31
3¾	4	56	3	57	3	15	2	49	2	28	2	10	1	58	1	38
4	5	14	4	11	3	27	2	59	2	37	2	18	2	6	1	44
4¼	5	33	4	26	3	40	3	10	2	47	2	27	2	13	1	50
4½	5	52	4	42	3	52	3	21	2	56	2	35	2	21	1	56
4¾	6	12	4	58	4	6	3	32	3	6	2	44	2	29	2	3
5	6	32	5	14	4	19	3	43	3	16	2	52	2	37	2	10
5½	7	15	5	48	4	47	4	8	3	37	3	11	2	54	2	24
6	7	52	6	18	5	12	4	29	3	56	3	28	3	9	2	36
6½	8	33	6	50	5	39	4	52	4	17	3	46	3	25	2	50
7	9	10	7	20	6	3	5	14	4	35	4	2	3	40	3	2
7½	9	54	7	55	6	32	5	39	4	57	4	21	3	58	3	16
8	10	28	8	22	6	54	5	58	5	14	4	36	4	11	3	27
8½	11	7	8	54	7	20	6	20	5	34	4	53	4	27	3	40
9	11	46	9	25	7	46	6	42	5	53	5	11	4	42	3	53
9½	12	25	9	56	8	12	7	5	6	12	5	28	4	58	4	6
10	13	9	10	31	8	40	7	30	6	34	5	47	5	16	4	20
10½	13	40	10	56	9	2	7	47	6	50	6	1	5	28	4	31
11	14	30	11	36	9	34	8	16	7	15	6	23	5	48	4	47
11½	15	2	12	2	9	55	8	34	7	31	6	37	6	1	4	58
12	15	44	12	35	10	23	8	58	7	52	6	55	6	18	5	14
12½	16	24	13	7	10	49	9	21	8	12	7	13	6	34	5	25
13	17	4	13	39	11	16	9	44	8	32	7	31	6	50	5	38
13½	17	32	14	2	11	34	10	0	8	46	7	43	7	1	5	47
14	18	20	14	40	12	6	10	27	9	10	8	4	7	20	6	3
14½	18	52	15	6	12	28	10	46	9	26	8	19	7	33	6	14
15	19	38	15	41	12	57	11	10	9	49	8	38	7	50	6	29
15½	20	24	16	19	13	28	11	38	10	12	9	0	8	10	6	44
16	20	58	16	46	13	50	11	57	10	29	9	13	8	23	6	55

TABLE FOR LATHE AND BORING-MILL TIME

Diam. of Work	Cutting Speed, Feet per Minute							
	15				20			
	Feeds, Inches per Rev.				Feeds, Inches per Rev.			
	1/32	1/8	1/4	1/2	1/32	1/8	1/4	1/2
2	13.404	3.351	1.676	0.838	10.053	2.513	1.257	0.628
2½	16.755	4.189	2.094	1.047	12.566	3.142	1.571	0.785
3	20.106	5.027	2.513	1.257	15.080	3.770	1.885	0.942
3½	23.457	5.864	2.932	1.466	17.593	4.398	2.199	1.010
4	26.808	6.702	3.351	1.676	20.106	5.027	2.513	1.257
4½	30.159	7.540	3.770	1.885	22.619	5.655	2.827	1.414
5	33.510	8.378	4.189	2.094	25.133	6.283	3.142	1.571
5½	36.861	9.215	4.608	2.304	27.646	6.912	3.456	1.728
6	40.212	10.053	5.027	2.513	30.159	7.540	3.770	1.885
6½	43.564	10.891	5.445	2.723	32.673	8.168	4.084	2.042
7	46.915	11.729	5.864	2.932	35.186	8.796	4.398	2.199
7½	50.266	12.566	6.283	3.142	37.699	9.425	4.712	2.356
8	53.617	13.404	6.702	3.351	40.212	10.053	5.027	2.513
8½	56.968	14.242	7.121	3.560	42.726	10.681	5.341	2.670
9	60.319	15.080	7.540	3.770	45.239	11.310	5.655	2.827
9½	63.670	15.917	7.959	3.979	47.752	11.938	5.969	2.985
10	67.021	16.755	8.378	4.189	50.266	12.566	6.283	3.142
10½	70.372	17.593	8.796	4.398	52.779	13.195	6.597	3.299
11	73.723	18.431	9.215	4.608	55.292	13.823	6.912	3.456
11½	77.074	19.268	9.634	4.817	57.805	14.451	7.226	3.613
12	80.425	20.106	10.053	5.027	60.319	15.080	7.540	3.770
12½	83.776	20.944	10.472	5.236	62.832	15.708	7.854	3.927
13	87.127	21.782	10.891	5.445	65.345	16.336	8.168	4.084
13½	90.478	22.620	11.310	5.655	67.859	16.965	8.482	4.241
14	93.829	23.457	11.729	5.864	70.372	17.593	8.796	4.398
14½	97.180	24.295	12.148	6.074	72.885	18.221	9.111	4.555
15	100.53	25.133	12.566	6.283	75.398	18.850	9.425	4.712
15½	103.88	25.971	12.985	6.492	77.912	19.478	9.739	4.869
16	107.23	26.808	13.404	6.702	80.425	20.106	10.053	5.027
16½	110.58	27.646	13.823	6.912	82.938	20.735	10.367	5.184
17	113.94	28.484	14.242	7.121	85.452	21.363	10.681	5.341
17½	117.29	29.322	14.661	7.330	87.965	21.991	10.996	5.498
18	120.64	30.159	15.080	7.540	90.478	22.620	11.310	5.655
18½	123.99	30.997	15.499	7.749	92.991	23.248	11.624	5.812
19	127.34	31.835	15.917	7.959	95.505	23.876	11.938	5.969
19½	130.69	32.673	16.336	8.168	98.018	24.504	12.252	6.126
20	134.04	33.510	16.755	8.378	100.53	25.133	12.566	6.283
21	140.74	35.186	17.593	8.796	105.56	26.389	13.195	6.597
22	147.45	36.861	18.431	9.215	110.58	27.646	13.823	6.912
23	154.15	38.537	19.268	9.634	115.61	28.903	14.451	7.226
24	160.85	40.212	20.106	10.053	120.64	30.159	15.080	7.540
25	167.55	41.888	20.944	10.472	125.66	31.416	15.708	7.854
26	174.25	43.564	21.782	10.891	130.69	32.673	16.336	8.168
27	180.96	45.239	22.620	11.310	135.72	33.929	16.965	8.482
28	187.66	46.915	23.457	11.729	140.74	35.186	17.593	8.796
29	194.36	48.590	24.295	12.148	145.77	36.443	18.221	9.111
30	201.06	50.266	25.133	12.566	150.80	37.699	18.850	9.425

These constants are for 1 foot of length at the cutting speeds and feeds given. The constants are derived from the circumference in inches divided by the feet in inches × the cutting speed in feet per minute.

Table for Lathe and Boring-Mill Time

Diam. of Work	Cutting Speed, Feet per Minute							
	25				30			
	Feeds, Inches per Rev.				Feeds, Inches per Rev.			
	1/32	1/8	1/4	1/2	1/32	1/8	1/4	1/2
2	8.042	2.011	1.005	0.503	6.702	1.675	0.838	0.419
2½	10.053	2.513	1.257	0.628	8.378	2.094	1.047	0.524
3	12.064	3.016	1.508	0.754	10.053	2.513	1.257	0.628
3½	14.074	3.519	1.759	0.880	11.729	2.932	1.466	0.733
4	16.085	4.021	2.011	1.005	13.404	3.351	1.676	0.838
4½	18.096	4.524	2.262	1.131	15.080	3.770	1.885	0.942
5	20.106	5.027	2.513	1.257	16.755	4.189	2.094	1.047
5½	22.117	5.529	2.765	1.382	18.431	4.608	2.304	1.152
6	24.127	6.032	3.016	1.508	20.106	5.027	2.513	1.257
6½	26.138	6.535	3.267	1.634	21.782	5.445	2.723	1.361
7	28.149	7.037	3.519	1.759	23.457	5.864	2.932	1.466
7½	30.159	7.540	3.770	1.885	25.133	6.283	3.142	1.571
8	32.170	8.042	4.021	2.011	26.808	6.702	3.351	1.676
8½	34.181	8.545	4.273	2.136	28.484	7.121	3.560	1.780
9	36.191	9.048	4.524	2.262	30.159	7.540	3.770	1.885
9½	38.202	9.550	4.775	2.388	31.835	7.959	3.979	1.990
10	40.212	10.053	5.027	2.513	33.510	8.378	4.189	2.094
10½	42.223	10.556	5.278	2.639	35.186	8.796	4.398	2.199
11	44.234	11.058	5.529	2.765	36.861	9.215	4.608	2.304
11½	46.244	11.561	5.781	2.890	38.537	9.634	4.817	2.499
12	48.255	12.064	6.032	3.016	40.212	10.053	5.027	2.513
12½	50.266	12.566	6.283	3.142	41.888	10.472	5.236	2.618
13	52.276	13.069	6.535	3.267	43.564	10.891	5.445	2.723
13½	54.287	13.572	6.786	3.393	45.239	11.310	5.655	2.827
14	56.297	14.074	7.037	3.519	46.915	11.729	5.864	2.932
14½	58.308	14.577	7.289	3.644	48.590	12.148	6.074	3.037
15	60.319	15.080	7.540	3.770	50.266	12.566	6.283	3.142
15½	62.329	15.582	7.791	3.896	51.941	12.985	6.493	3.246
16	64.340	16.085	8.042	4.021	53.617	13.404	6.702	3.351
16½	66.351	16.588	8.294	4.147	55.292	13.823	6.912	3.456
17	68.361	17.090	8.545	4.273	56.968	14.242	7.121	3.560
17½	70.372	17.593	8.796	4.398	58.643	14.661	7.330	3.665
18	72.382	18.096	9.048	4.524	60.319	15.080	7.540	3.770
18½	74.393	18.598	9.299	4.650	61.994	15.499	7.749	3.875
19	76.404	19.101	9.550	4.775	63.670	15.917	7.959	3.979
19½	78.414	19.604	9.802	4.901	65.345	16.336	8.168	4.084
20	80.425	20.106	10.053	5.027	67.021	16.755	8.378	4.189
21	84.446	21.112	10.556	5.278	70.372	17.593	8.796	4.398
22	88.467	22.117	11.058	5.529	73.723	18.431	9.215	4.608
23	92.489	23.122	11.561	5.781	77.074	19.268	9.634	4.817
24	96.510	24.127	12.064	6.032	80.425	20.106	10.053	5.027
25	100.53	25.133	12.566	6.283	83.776	20.944	10.472	5.236
26	104.55	26.138	13.069	6.535	87.127	21.782	10.891	5.445
27	108.57	27.143	13.572	6.786	90.478	22.620	11.310	5.655
28	112.59	28.149	14.074	7.037	93.829	23.457	11.729	5.864
29	116.62	29.154	14.577	7.289	97.180	24.295	12.148	6.074
30	120.64	30.159	15.080	7.540	100.53	25.133	12.566	6.283

Table for Lathe and Boring-Mill Time

Diam. of Work	Cutting Speed, Feet per Minute: 35 — Feeds, Inches per Rev.				40 — Feeds, Inches per Rev.			
	1	½	¼	⅛	1	½	¼	⅛
2	5.745	1.436	0.718	0.359	5.027	1.257	0.628	0.314
2½	7.181	1.795	0.898	0.449	6.283	1.571	0.785	0.393
3	8.617	2.154	1.077	0.539	7.540	1.885	0.942	0.471
3½	10.053	2.513	1.257	0.624	8.796	2.199	1.100	0.550
4	11.489	2.872	1.436	0.718	10.053	2.513	1.257	0.628
4½	12.925	3.231	1.616	0.808	11.310	2.827	1.414	0.707
5	14.362	3.590	1.795	0.808	12.566	3.142	1.571	0.785
5½	15.798	3.949	1.975	0.987	13.823	3.456	1.728	0.864
6	17.234	4.308	2.154	1.077	15.080	3.770	1.885	0.942
6½	18.670	4.668	2.334	1.167	16.336	4.084	2.042	1.021
7	20.106	5.027	2.513	1.257	17.593	4.398	2.199	1.100
7½	21.542	5.386	2.693	1.346	18.850	4.712	2.356	1.178
8	22.979	5.745	2.872	1.436	20.106	5.027	2.513	1.257
8½	24.415	6.104	3.052	1.526	21.363	5.341	2.670	1.335
9	25.851	6.463	3.231	1.616	22.620	5.655	2.827	1.414
9½	27.287	6.822	3.411	1.705	23.876	5.969	2.985	1.492
10	28.723	7.181	3.590	1.795	25.133	6.283	3.142	1.571
10½	30.159	7.540	3.770	1.885	26.389	6.597	3.299	1.649
11	31.596	7.899	3.949	1.975	27.646	6.912	3.456	1.728
11½	33.032	8.258	4.129	2.064	28.903	7.226	3.613	1.806
12	34.468	8.617	4.308	2.154	30.159	7.540	3.770	1.885
12½	35.904	8.976	4.488	2.244	31.416	7.854	3.927	1.964
13	37.340	9.335	4.668	2.334	32.673	8.168	4.084	2.042
13½	38.776	9.694	4.847	2.424	33.929	8.482	4.241	2.121
14	40.212	10.053	5.027	2.513	35.186	8.796	4.398	2.199
14½	41.649	10.412	5.206	2.603	36.443	9.111	4.555	2.278
15	43.085	10.771	5.386	2.693	37.699	9.425	4.712	2.356
15½	44.521	11.130	5.565	2.783	38.956	9.739	4.869	2.435
16	45.957	11.489	5.745	2.872	40.212	10.053	5.027	2.513
16½	47.393	11.848	5.924	2.962	41.469	10.367	5.184	2.592
17	48.829	12.207	6.104	3.052	42.726	10.681	5.341	2.670
17½	50.266	12.566	6.283	3.142	43.982	10.996	5.498	2.749
18	51.702	12.925	6.463	3.231	45.239	11.310	5.655	2.828
18½	53.138	13.284	6.642	3.321	46.496	11.624	5.812	2.906
19	54.574	13.644	6.822	3.411	47.752	11.938	5.969	2.985
19½	56.010	14.003	7.001	3.501	49.009	12.252	6.126	3.063
20	57.446	14.362	7.181	3.590	50.266	12.566	6.283	3.142
21	60.319	15.080	7.540	3.770	52.779	13.195	6.597	3.299
22	63.191	15.798	7.899	3.949	55.292	13.823	6.912	3.456
23	66.063	16.516	8.258	4.129	57.805	14.451	7.226	3.613
24	68.936	17.234	8.617	4.308	60.319	15.080	7.540	3.770
25	71.808	17.952	8.976	4.488	62.832	15.708	7.854	3.927
26	74.680	18.670	9.335	4.668	65.345	16.336	8.168	4.084
27	77.553	19.388	9.694	4.847	67.859	16.965	8.482	4.241
28	80.425	20.106	10.053	5.027	70.372	17.593	8.796	4.398
29	83.297	20.824	10.412	5.206	72.885	18.221	9.111	4.555
30	86.170	21.542	10.771	5.386	75.398	18.850	9.425	4.712

Table for Lathe and Boring-Mill Time

Diam. of Work	Cutting Speed, Feet per Minute							
	50				60			
	Feeds, Inches per Rev.				Feeds, Inches per Rev.			
	1/32	1/16	1/8	1/4	1/32	1/16	1/8	1/4
2	4.021	1.005	0.503	0.251	3.351	0.838	0.419	0.209
2½	5.027	1.257	0.628	0.314	4.189	1.047	0.524	0.262
3	6.032	1.508	0.754	0.377	5.027	1.257	0.628	0.314
3½	7.037	1.759	0.880	0.440	5.864	1.466	0.733	0.367
4	8.042	2.011	1.005	0.503	6.702	1.676	0.838	0.419
4½	9.048	2.262	1.131	0.565	7.540	1.885	0.942	0.471
5	10.053	2.513	1.257	0.628	8.378	2.094	1.047	0.524
5½	11.058	2.765	1.382	0.691	9.215	2.304	1.152	0.576
6	12.064	3.016	1.508	0.754	10.053	2.513	1.257	0.628
6½	13.069	3.267	1.634	0.817	10.891	2.723	1.361	0.681
7	14.074	3.519	1.759	0.880	11.729	2.932	1.466	0.733
7½	15.080	3.770	1.885	0.942	12.566	3.142	1.571	0.785
8	16.085	4.021	2.011	1.005	13.404	3.351	1.676	0.838
8½	17.090	4.273	2.136	1.068	14.242	3.560	1.780	0.890
9	18.096	4.524	2.262	1.131	15.080	3.770	1.885	0.942
9½	19.101	4.775	2.388	1.194	15.917	3.979	1.990	0.995
10	20.106	5.027	2.513	1.257	16.755	4.189	2.094	1.047
10½	21.112	5.278	2.639	1.319	17.593	4.398	2.199	1.100
11	22.217	5.529	2.765	1.382	18.431	4.608	2.304	1.152
11½	23.122	5.781	2.890	1.445	19.268	4.817	2.409	1.204
12	24.127	6.032	3.016	1.508	20.106	5.027	2.513	1.257
12½	25.133	6.283	3.142	1.571	20.944	5.236	2.618	1.309
13	26.138	6.535	3.267	1.634	21.782	5.445	2.723	1.361
13½	27.143	6.786	3.393	1.696	22.620	5.654	2.827	1.414
14	28.149	7.037	3.519	1.759	23.457	5.864	2.932	1.466
14½	29.154	7.289	3.644	1.822	24.295	6.074	3.037	1.518
15	30.159	7.540	3.770	1.885	25.133	6.283	3.142	1.571
15½	31.165	7.791	3.896	1.948	25.971	6.493	3.246	1.623
16	32.170	8.042	4.021	2.011	26.808	6.702	3.351	1.676
16½	33.175	8.294	4.147	2.073	27.646	6.912	3.456	1.728
17	34.181	8.545	4.273	2.136	28.484	7.121	3.560	1.780
17½	35.186	8.796	4.398	2.199	29.322	7.330	3.665	1.833
18	36.191	9.048	4.524	2.262	30.159	7.540	3.770	1.885
18½	37.197	9.299	4.650	2.325	30.997	7.749	3.875	1.937
19	38.202	9.550	4.775	2.388	31.835	7.959	3.979	1.990
19½	39.207	9.802	4.901	2.450	32.673	8.168	4.084	2.042
20	40.212	10.053	5.027	2.513	33.510	8.378	4.189	2.094
21	42.223	10.556	5.278	2.639	35.186	8.796	4.398	2.199
22	44.234	11.058	5.529	2.765	36.861	9.215	4.608	2.304
23	46.244	11.561	5.781	2.890	38.537	9.634	4.817	2.409
24	48.255	12.064	6.032	3.016	40.212	10.053	5.027	2.513
25	50.266	12.566	6.283	3.142	41.888	10.472	5.236	2.618
26	52.276	13.069	6.535	3.267	43.564	10.891	5.445	2.723
27	54.287	13.572	6.786	3.393	45.239	11.310	5.655	2.827
28	56.297	14.074	7.037	3.519	46.915	11.729	5.864	2.932
29	58.308	14.577	7.289	3.644	48.590	12.148	6.074	3.037
30	60.319	15.080	7.540	3.770	50.266	12.566	6.283	3.142

Accurate Tool Setting with Compound Rest

A compound rest equipped with micrometer dial may be used for making extremely minute adjustments by merely swiveling it to any ratio desired, for instance:

If it is set at 45 degrees, one 0.001-in. division on the dial will advance the tool 0.0005 in. or remove 0.001 in. on diameter of work. If set at 30 degrees, the tool advance will be 0.00033 in. and if set at 50 degrees, the advance is 0.00055 in. The following is the formula:

A = Advance of tool.
B = Amount removed on diameter of work.
C = Number of degrees of set over of compound rest.
D = 90 degrees.
E = 0.001 division on dial.

$$A = E \div \frac{C}{D} \quad B = 2A \quad C = D \div \frac{E}{A}$$

Cutting Lubricants

Cast iron is usually worked dry, but when hard cast-iron gears are to be cut, as with three cutters, the first cut through will work better with strong soda water. It makes an objectionable mess, but the work will be done faster and the cutters keep sharper longer than with the dry process of cutting.

Brass and babbitt are usually cut dry, but to hand-ream brass and babbitt is sometimes difficult if the reamer is a little dull. Kerosene and turpentine are used with good results. Cast iron can be hand-reamed easily with tallow and graphite, mixed, and the hole will be kept just the size of the reamer. Copper can be worked well with lard-oil and turpentine mixed.

In boring babbitt bushings and rod boxes in a lathe or boring mill, it is very difficult to work the material dry as the chips have a great tendency to roll around the tool and into a hard ball, tearing the metal and making a rough ragged hole. In this case kerosene and lard-oil mixed will work well.

Cheap oil is sometimes used as a lubricant for cutting, but soap water or soda water is better for iron and steel shafting and with a sharp tool and light finish cut the work will be smooth enough to polish without filing.

Rawhide is a very peculiar substance to work, and to drill it with a twist drill is a tedious job, as the flutes will clog and stick if run dry. A cake of soap held against the drill will prevent all trouble and sticking of drills. It is bad practice to use oil on rawhide as it injures the fiber and loosens the glue. Drills should be run at very high speed in rawhide to work well.

Turpentine is good in some cases where fitting is done, such as scraping lay-out plates, or face plates. Oil will form a coating so that marks cannot be seen plainly, but turpentine will prove beneficial on this kind of work if used freely. The marks can be seen

plainly, and the work is a great deal easier to scrape than with an oil surface, as the oil glazes over the surface and makes it hard to start the scraper cutting.

Lubricants for Threading

Hard rubber and fiber is threaded without any lubrication.

Aluminum.—For aluminum, kerosene with enough cutting oil to give it a body. There are different alloys of aluminum, and while one lubricant would be all right for a certain aluminum stock, it might not be all right for another. For many purposes a soluble cutting oil is satisfactory.

Basic Steel.—The same good mineral lard oil that was used for threading Bessemer steel has worked well for basic steel.

Bessemer Steel.—In cutting the regular grades of Bessemer steel a good mineral lard oil has been used with results wholly satisfying. Sometimes the mineral lard oil has been mixed with a certain percentage of ordinary kerosene oil, ranging from 25 to 50 per cent, according to the nature of the work.

Copper.—Frequently cut dry, but good cooling compound preferred.

Cast Iron.—Mineral lard oil.

Monel Metal.—In threading monel metal a compound of white lead and oil has been used successfully. Others claim better results from red lead and oil. If the lead and oil are mixed to the consistency of thin glue and applied to the work, there would probably be no difficulty in cutting monel metal successfully, so far as the lubricant is concerned.

Phosphor Bronze Studs.—Mineral lard oil straight, or diluted with 25 per cent kerosene oil.

Soft Drawn Steel and Soft Steel Forgings.—Prime lard oil, or the compound for general threading, given here:

Compound for General Threading

A very satisfactory compound advised by Geometric Tool Company for general screw-thread cutting is made as follows:

40 gallons of water.
10 gallons of mineral lard oil (good grade).
2½ pounds of soda ash (exact quantity).

This compound has been used with excellent results when threading the following materials:

Cast and bar brass, machine steel, malleable iron, tobin bronze, tool steel, drawn steel tubing or shells, vanadium steel, Bessemer steel, pressed steel, brass tubing, copper lead, monel metal, nickel steel, basic or open-hearth steel, cold-rolled stock.

Half the quantity, or 5 gallons only, of mineral lard oil is sometimes used in making up the compound, where a cooling rather than lubricating element is desirable. This compound has worked well on pressed steel where every other lubricant failed.

An addition of sulphur to the oil has proved very helpful in some cases.

ESTIMATING MACHINING TIME

These speeds and feeds will be found conservative for average work.

TABLE OF CUTTING SPEEDS FOR ESTIMATING PURPOSES

Material	Cutting Speed in Feet per Minute
Cast iron	50–60
Cast steel	60
Malleable iron	70
Machine steel forgings (15- to 20-point carbon)	60– 70
Machine steel bar stock	60– 70
Tool steel forgings	35– 40
Steel alloys containing nickel and chromium	30– 50
Yellow brass	150–200
Composition brass	120–150
Bronzes—manganese and phosphor bronzes usually require speeds approximating those for cast iron. Speed depends considerably on whether lubricant is used or not	30– 80
Aluminum—aluminum alloys usually cut freely with lubricant, but the nature of the alloy and the shape of the tools are important factors	150–300

Stellite tools will run satisfactorily at greater speeds and with coarser feeds in the majority of cases.

It is difficult to give thoroughly reliable data on feeds, but a few examples may be of interest. For estimating purposes, and always assuming that the normal finish allowance is provided, the following notes may be used as a basis in setting feeds. There are so many factors to be taken into consideration, however, that variations of from 20 to 30 per cent from the figures given are often correct under certain conditions.

Cast Iron

For roughing cuts on diameters up to 8 inches the feed may range from $\frac{1}{32}$ to $\frac{1}{16}$ inch. Feeds for finishing cuts may be about the same, and the speeds increased 25 per cent or more, or the feeds may be doubled, using a slight increase of speed and broad-nosed tools. On diameters where the finish allowance is from $\frac{1}{4}$ to $\frac{3}{8}$ inch, the feeds for roughing cuts may vary from $\frac{1}{16}$ to $\frac{1}{8}$ inch, and for finishing cuts higher speeds can be used with finer feeds, or slower speeds with an increase of feed, if broad-nosed tools are used. On large work, final finishing cuts are sometimes taken at cutting speeds 50 per cent higher than for roughing cuts, and with a feed of from $\frac{1}{2}$ to $\frac{3}{4}$ inch per revolution with very broad-nosed tools and when great accuracy is not required. These statements are based on actual practice and, while they cannot be considered as positive

in their nature, they will be found to answer very well for a great proportion of cast-iron work.

Cast Steel

Roughing cut feeds on diameters up to 8 inches will vary from 0.020 to 0.040 inch. Finishing feeds should be decreased by 25 to 50 per cent, while speeds can be correspondingly increased. For larger diameters, where the finish allowance is from $\frac{1}{4}$ to $\frac{5}{16}$ inch, the feeds for roughing may vary from 0.040 to 0.060 inch, and for finishing cuts on large diameters, where considerable accuracy is required, the feeds should be 50 per cent finer with speeds increased 25 per cent or more. Broad-nosed tools cannot be used to advantage for finishing steel castings, as they are inclined to tear the metal and leave it rough. The use of lubricant is assumed when cutting steel castings, and the tools must be lipped and ground to suit the material.

Malleable Iron

Roughing cuts on diameters up to 8 inches can be made with feeds from $\frac{1}{32}$ to 0.040 inch, and finishing feeds are about the same as for cast iron. The use of lubricant for malleable iron is recommended.

Machine Steel Forgings

The feeds will range from 0.020 to 0.040 inch for roughing cuts on diameters up to 8 inches. For finishing the feeds should be decreased from 20 to 30 per cent and the speeds can usually be increased from 30 to 50 per cent. For larger diameters, when the finish allowance is considerably greater, the maximum feed can seldom be over $\frac{1}{16}$ inch, and in many cases not more than $\frac{1}{32}$ inch is permissible. Finishing cuts on large diameters are generally about the same as for cast steel, always assuming that a plentiful supply of lubricant is provided.

Machine Steel Bar Stock

It is difficult to give feeds on this class of work, because diameters are frequently reduced by taking a very deep cut with a fine feed, but when box tools or universal turning tools are used and when the stock reduction is not more than $\frac{3}{16}$ to $\frac{1}{4}$ inch, a feed of from 0.020 to 0.040 inch can often be used. In forming cuts and for greater stock reductions the feeds may vary from 0.002 to 0.015 inch, depending upon the shape of the form to be cut and the method of applying the tools. Finishing cuts are seldom made with a coarse feed, but speeds are increased in many cases as much as 50 per cent.

Tool Steel Forgings

Roughing cuts on small diameters up to 6 or 8 inches with a depth of cut not exceeding $\frac{1}{4}$ inch can usually be machined with feeds from 0.012 to 0.020 inch, and occasionally a feed of 0.030 inch can be used, if the forgings have been thoroughly pickled and annealed. For finishing cuts the feeds must be finer, although the speeds can usually be increased about 25 per cent. On large diameters feeds from $\frac{1}{32}$ to $\frac{3}{64}$ inch are possible in some cases,

when the depth of the cut does not exceed $\frac{3}{8}$ inch, but in estimating work of this kind it is seldom safe to exceed a feed of $\frac{1}{32}$ inch for roughing cuts. Finishing cuts for large diameters can be slightly coarser, if great accuracy is not required in the product and if the appearance of the work is not of primary importance. Otherwise fine feeds must be used and the tools "lipped" to curl the chip, in order to remove the metal easily and leave the surface smooth and clean. Lubricant must always be used on this kind of work and any boring tools for deep holes must be designed so that lubricant can be carried to the cutting edges.

Steel Alloys

Roughing cut feeds are usually about the same as for tool steel forgings. It is safe to follow the procedure noted in the preceding paragraph, unless it is possible to obtain a sample of the alloy on which tests can be made to determine the feeds and speeds possible.

Yellow Brass

For roughing cuts on work up to 8 inches in diameter and having a finish allowance of from $\frac{1}{16}$ to $\frac{1}{8}$ inch, feeds from 0.020 to 0.040 inch can be safely used. It is not advisable to go much beyond these feeds, as there is danger of tearing the metal, so that the finishing cuts will not remove the marks made in roughing. For finishing cuts, tools should be ground with a "drag" and, when only a small amount is allowed for the finishing cuts, the feeds can be quite coarse, even with very high speeds. For roughing cuts on large diameters when the finish allowance does not exceed $\frac{1}{4}$ inch, feeds as coarse as $\frac{1}{16}$ or even $\frac{3}{32}$ inch can be used in extreme cases. It is not advisable, however, to attempt to use too coarse feeds for the reason previously stated. In finishing large diameters the same rule applies as that mentioned for small diameters, that is, coarse feeds and high speeds, provided the tool is ground with a drag. Some operators prefer to use finer feeds in finishing, but this is not necessary if judgment is used in grinding tools.

Composition Brass

Roughing and finishing cuts are approximately the same as for yellow brass, although they should be slightly more conservative, as the composition is generally somewhat harder than ordinary brass.

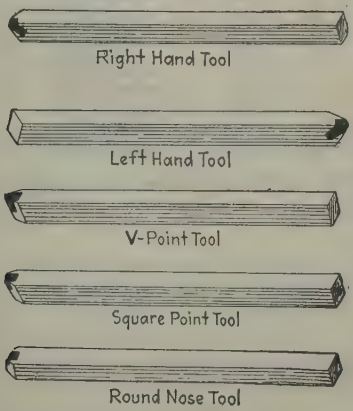
Bronzes

For roughing work up to 8 inches in diameter where finish allowances do not exceed $\frac{1}{16}$ to $\frac{3}{32}$ inch on a side, feeds from 0.020 to 0.040 inch can generally be used, depending considerably on the nature of the alloy. Phosphor bronze and manganese bronze are hard in their composition and the feeds used must not be too great. In addition to this, the scale on bronze castings is extremely hard and has a strong abrasive action on the tools, so that they dull very rapidly. The speeds and feeds used in finishing can be considerably increased, but if good work is required, it is not advisable to use very coarse feeds, and an increase of 25 per cent over the roughing cuts will usually be found satisfactory. For larger

diameters when the finish allowances approach $\frac{1}{4}$ to $\frac{5}{16}$ inch, the feeds for roughing can frequently be 0.030 to 0.060 inches. In finishing large diameters slightly coarser feeds can be used than for the smaller sizes, but really coarse feeds cannot be applied to advantage if a good finish is desired.

Aluminum

The feeds for roughing this class of material vary greatly on account of the difference in the composition of the alloy. In general, very coarse feeds can be used for both large and small diameters, provided the tool is suitably ground. The writer has seen aluminum castings 10 inches in diameter machined dry at a cutting speed of 300 feet per minute and with a feed of $\frac{1}{8}$ inch per revolution. It would not be advisable, however, to use speeds and feeds of this kind for estimating, as the nature of the alloy might easily make a great difference. Feeds for the majority of roughing cuts on small diameters, when the finish allowance is approximately $\frac{1}{8}$ inch, can vary from 0.040 to 0.080 inch, and in extreme cases even more than this. Finishing cuts are possible at feeds from $\frac{1}{8}$ to $\frac{1}{2}$ inch per revolution, when broad-nosed tools are used. For large diameters an increase of about 25 per cent is permissible, both in roughing and finishing. It is advisable to be somewhat conservative in setting feeds for this class of work, but it will, in general, be found that the production time is much better than the estimated time, provided the operator uses judgment and tries to obtain the highest possible production.



DIAMOND-TIPPED TURNING TOOLS

These tools are used for turning fiber, hard rubber, paper rolls and some metals. They maintain a cutting edge almost indefi-

nitely and leave a smooth finish. Diamond-pointed bits are used in boring bars for aluminum crank cases, etc., and bronze bushings are bored and turned with diamond tools in some shapes.

Use of Diamond Tools.—Mica can be readily turned with a diamond. One user reports turning mica $\frac{5}{8}$ diameter by 2 inches long at 1,040 r.p.m. or 175 feet per minute at the rate of 600 per day for 5 months. A steel tool lasted for only three pieces.

Another user bores out steel bushings much faster than by grinding. The bushings were $\frac{1}{4}$ by $\frac{7}{8}$ inch and averaged 0.002 inch out of true, before boring.

Sizes of Centers in Arbors

The accompanying table gives a few of the sizes of center drills and countersinks used by the Remington Arms Co., Ilion, N. Y., on its mandrels.

A Diam. of Mandrel	*B* Largest Diam. of Center	*C* Size of Drill	*D* Depth of Hole
0.25	0.12	0.052 (#55)	0.15
0.50	0.25	0.102 (#38)	0.30
0.75	0.38	0.152 (#24)	0.45
1.00	0.50	0.199 (#8)	0.60
1.25	0.53	0.213 (#3)	0.64
1.50	0.56	0.228 (#1)	0.68
1.75	0.59	0.238 (#B)	0.73
2.00	0.62	0.250 (#3)	0.77
2.50	0.69	0.272 (#1)	0.85
3.00	0.75	0.302 (#N)	0.94
3.50	0.82	0.323 (#P)	1.00
4.00	0.88	0.348 (#S)	1.10

TURNING TAPERS BETWEEN CENTERS

Tapers can be cut between lathe centers either by setting over the tail center or by using a taper attachment. In either case the angle must be one-half the difference in diameters between the two ends of the taper, if it extended the whole length of the piece. To turn a piece 20 inches long, 5 inches at one end and 3 inches at the other, as Fig. 1, must have the tail stock set over 1 inch, this being one-half of the difference between 5 and 3.

If the taper extends only half the length of the piece with the same difference in diameter, the tail stock must be set over twice as

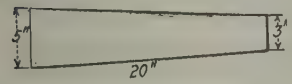


FIG. 1



FIG. 2

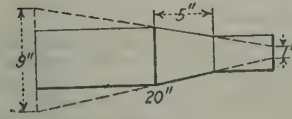


FIG. 3
Location of Tapers

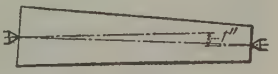


FIG. 4

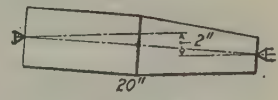


FIG. 5



FIG. 6
Set-over in Lathe

far, or 2 inches, for the true taper is now from 3 inches at the small end and 7 inches at the large end. The difference is 4 inches, making it necessary to set the tail stock over 2 inches.

A third case is shown in Fig. 3, where the taper is not at either end. With the same difference between large and small diameters the taper is again twice as great as in Fig. 2, the dotted lines showing the taper extended the whole length of the piece. This would be 1 inch at the small end and 9 inches at the large end, a difference of 8 inches, requiring a setover of 4 inches.

Extreme tapers of this kind are not easy to turn by setting over the tail stock. The point of the cutting tool must be set at the same height as the lathe centers.

GRINDING AND LAPPING

GRINDING WHEELS AND GRINDING

The Commercial Abrasives

EMERY, corundum, carborundum, crystolon, alundum and aloxite are the ordinary commercial abrasive materials. They vary in hardness, though it does not follow that the hardest grit is the best for cutting purposes; the shape and form of fracture of the particles must also be taken into consideration. We may imagine a wheel made up from diamonds, the hardest substance in nature, and whose individual kernels were of spherical form; it is quite obvious that it would be of little service as a cutting agent; on the other hand, if these kernels were crystalline or conchoidal in form it would probably be the ideal grinding wheel.

Emery is a form of corundum found with a variable percentage of impurity; it is of a tough consistency and breaks with a conchoidal fracture.

Corundum is an oxide of aluminum of a somewhat variable purity, according to the neighborhood in which it is mined; its fracture is conchoidal and generally crystalline.

Carborundum and crystolon are of silicide of carbon, which is a product of the electric furnace; it breaks with a sharp crystalline fracture.

. Alundum and aloxite are also artificial products, being fused oxide of aluminum. They are of uniform quality, of about 98 per cent of purity, breaking with a sharp, conchoidal crystalline fracture and having all the toughness of emery. There are also other trade names for similar abrasives.

Grit and Bond

A GRINDING wheel is made up of the "grit" or cutting material, and the bond. The cutting efficiency of a wheel depends largely on the grit; the guide of hardness depends principally on the bonding material used. The efficiency in grinding a given metal is dependent largely upon the "temper," or resistance to fracture, and, as noted above, upon the character of fracture of the grit or cutting grains of the wheel.

The function of the bond is not only to hold the cutting particles of the wheel together and to give the wheel the proper factor of safety at the speed it is to be run, but it must also be possible to vary its tensile strength to fit the work it is called upon to do. We often hear the operator say that the wheel is too hard or too soft. He means that the bond retains the cutting teeth so long that they become dulled, and this wheel is inefficient; or, in the case of a soft wheel, the bond has not been strong enough to hold the cutting teeth and they are pulled out of the wheel before they have done the work expected.

The bond to be used for a given operation depends on the wheel and work speeds, area of wheel in contact with the work, vibration in wheel spindle or work, shape and weight of work and many other like variables. Wheels are bonded by what are known as the

vitrified, silicate, elastic and rubber processes. No one bond makes the best wheel for all purposes; each one has its field.

The vitrified bond is made of fused clays, is unchanged by heat or cold and can be made in a greater range of hardness than any other bond. It does not completely fill the voids between the grains, and, therefore, a wheel bonded in this way having more clearance than any other is adaptable for all kinds of grinding except where the wheel is not thick enough to withstand side pressure. This bond has no elasticity.

The silicate bond is composed of clays fluxed by silicate of soda at low temperatures. It is not as stable as the vitrified bond as regards dampness, gives less clearance between grains, and has a range of hardness below that of the vitrified in the harder grades. This bond has no elasticity and will not make a safe wheel of extreme thinness.

The elastic bond is composed of shellac and other gums. It completely fills the voids of the wheel, has a limited range of grades, has a high tensile strength and elasticity and can be used for the making of very thin wheels. The rubber or vulcanite bond has the general characteristics of the elastic, but its grades of hardness cannot be varied to the same extent and its uses are limited.

Grain and Grade

GRINDING wheels are made in various combinations of coarseness and hardness to meet the variety of conditions under which they are used. The cutting material is crushed and graded from coarse to fine in many sizes designated by number. By No. 20 grain is meant a size that will pass through a grading sieve having 20 meshes to the linear inch.

The term "grade" refers to the degree of hardness of the wheel or the resistance of the cutting particles under grinding pressure. A wheel from which the cutting particles are easily broken, causing it to wear rapidly, is called soft, while one which retains its particles longer is called hard.

Use of Water

Water should be applied directly at the *grinding point*, and must be delivered with sufficient force to keep the wheel face clean. If this is not done a kind of mud accumulates at the grinding point, causing glazing. Water is, or should be, used in grinding process not as a means of quenching heat but rather to prevent its creation and radiation, and therefore the actual grinding point is the best place to apply it.

It is a necessary means of keeping the work at an equable temperature so as to obviate distortion and to make the matter of taking dimensions an actuality rather than a guessing matter. This applies equally to all kinds of grinding.

The Use of Diamonds

A diamond is an essential part of a grinding machine's equipment and should have careful consideration, as it is sometimes a very expensive item. The diamonds should be the hardest rough stones procurable, and the larger stones are cheaper in the end. A large stone allows of a more secure hold in its setting, and so the danger of losing it is reduced. The diamond tool should always be

held by mechanical means when it is in use, except in cases which are unavoidable.

As a means of preserving the diamond, a full stream of water should be run on it when in use, and many light cuts are preferable to a few heavy ones. The main thing is to watch that it does not get unduly heated, for this is disastrous. Where large quantities of material have to be removed from a wheel, the ordinary wheel dresser may be employed to reduce the bulk of the stock, and the diamond only used for finishing to shape.

Setting the Diamonds

DIAMONDS may be obtained ready fixed in suitable holders, or the rough stones may be bought and set by any competent toolmaker. The illustrations show various methods by which they may be held securely, and require but little explanation. First, Fig. 1 is the method most commonly used, the diamond being either peened or



FIG. 1

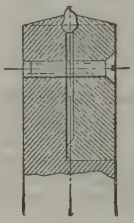


FIG. 2



FIG. 3

brazed in position. One disadvantage of this method is that the diamond is apt to break with a chance blow of the peening chisel, or the heat from brazing will sometimes cause fractures; neither is it so easily reset when its point becomes dulled as are the other settings shown. Fig. 2 requires no explanation, except that it is advisable to pack the diamond with shredded asbestos fiber to act as a cushion; this method allows of quick resetting. Fig. 3 consists of a small steel cap tapped out to fit the stock as shown. Enough shredded asbestos fiber is inserted between the diamond and stock to hold it firmly in position. This method also allows of quick and safe resetting.

ARTIFICIAL ABRASIVES AND GRINDING WHEELS

Artificial aluminous oxide is an abrasive material widely employed in the manufacture of grinding wheels.

Owing to the great variety of names under which this very useful material is sold, some who may be quite familiar with artificial aluminous oxide, might not recognize it by that particular title. The following list of names, from the *American Machinist*, are known to the trade.

Alowalt, Aloxite, Aluminoid, Alundum, Bathite, Boro-Carbone, Borolon, Clevite, Excelite, Hytens, Natalite, Orelite, Oxaluma, Oxylum, Rex, Rexite, Staralox, Sterlite.

FACTORS AFFECTING GRINDING-WHEEL SELECTION

The selection of a grinding wheel for a given piece of work is not a guess—neither is it calculable by mathematics. Grinding plays an important part in our modern manufacturing processes, and an understanding of the factors involved in selecting a grinding wheel for a certain job is extremely helpful to the shop superintendent, methods engineer, foreman or workman. The following general factors govern grinding-wheel selection:

Given conditions:
1. Material to be ground.
2. Amount of material to be removed and finish desired.
3. Arc of contact.
4. Type of grinding machine.

Influential variable factors:
1. Wheel speed.
2. Work speed (or pressure if hand grinding).
3. Condition of machine.
4. Skill of the workman.

1. Material to be Ground.—The composite effect of several physical properties of a material to be ground largely governs the selection of the type of abrasive to be used. For materials that are neither very brittle nor very easily penetrated, crystalline aluminum oxide wheels have been found most suitable. Most materials for which this abrasive is better adapted are comparatively high in tensile strength. Therefore, beginning with the hardest and toughest of alloy steels, down to and including the tougher grades of bronze, *aluminum oxide* grinding wheels should be used.

For materials that are very easily penetrated, such as leather, and for those which are hard but very brittle, such as stone, silicon carbide wheels are more suitable. Cast and chilled irons offer moderate resistance to penetration and are sufficiently brittle compared with hardened steel to make silicon carbide the more effective abrasive for them. Also other materials of low tensile strength, such as soft brasses and bronzes, aluminum and copper, are more efficiently ground with *silicon carbide* grinding wheels.

2. Amount of Material to be Removed.—The amount of material to be removed by the grinding wheel and the finish desired influence the selection of the grit size, because, where comparatively large amounts of material have to be removed by grinding, the coarser grain combinations should be employed to facilitate the rapid removal of stock. This applies particularly to hand-grinding operations like snagging castings, where finish is no consideration, but rapid cutting qualities are essential.

Finish is dependent to a considerable extent on grit size used, except on machine-grinding operations, where proper truing and dressing facilities afford a means of obtaining fine finish without the sacrifice of production usually accompanying the use of fine grit wheels.

3. Arc of Contact.—The arc of contact, or the area of contact, has a very important bearing on the grain and grade selection, By

the "arc of contact" is meant the length of the arc (measured along the periphery of the wheel) that is in contact with the work being ground. The two extremes of the length of this arc are illustrated by Figs. 4 and 7. The difference in the length of the arc of contact in these two extremes is actually rather small, but the effect of this difference on the grinding wheel is great. In the first case a medium-hard wheel is required, whereas only the softest grades will grind satisfactorily in the second case.

In the case of cup or cylinder wheels where the grinding is done on the rim, the arc of contact develops into an area of contact and the effect of a change from a small area to a large area is even more marked than with a straight wheel. The extremes here range from the grinding of steel balls, where practically "point contact" exists, to the grinding of broad, flat surfaces. To select a wheel suitable to the variations in the area of contact, grades F to Z (Norton) have to be employed.

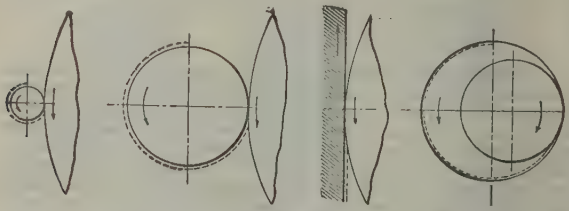


FIG. 4 Grinding Small Dia. FIG. 5 Grinding Large Dia. FIG. 6 Grinding Flat Surface FIG. 7 Internal Grinding

Contact of Grinding Wheel

The "arc of contact" and "area of contact" should not be confused with the "width of contact." By "width of contact" is meant the width of the wheel in contact with the work in the case of cylindrical grinding, or the width of the rim in the case of cup and cylinder wheels. Width of contact has practically no effect on the cutting action of a wheel, provided, of course, pressure per unit area remains constant and there is sufficient power in the drive. In other words, there should be no difference in the cutting action of a wheel 1 inch wide and another 4 inches wide, or a cup with 1-inch rim or one with a 2-inch rim, provided the pressure per unit area remains the same.

4. Type of Grinding Machine.—In the majority of cases when a grinding wheel has to be selected for a given job, the grinding machine is already available and becomes an important factor in grinding-wheel selection. Heavy, rigidly constructed machines take softer wheels than lighter, more flexible types. Some machines set up greater vibrations than others, thus calling for finer and harder wheels. The combination of speeds and feeds on some precision machines makes the use of different kinds of wheels

necessary. Plane-surface grinding machines making use of the rim of a cup or cylinder wheel require much softer wheels than plane-surface machines using the periphery of a straight or disk wheel.

Influential Variable Factors

1. Wheel Speed.—Too slow a speed means waste of abrasive without getting much useful work in return, and an excessive speed may retard cutting and if carried too far might become dangerous. Run a grinding wheel at somewhere near the speed recommended by the maker, as he has found by years of experience that certain speeds work better than others. The grits and grades usually recommended for certain grinding operations are based on the assumption that approximately the recommended speeds will be employed. If for some reason they cannot be, then the grade at least must be changed to suit this condition.

RECOMMENDED WHEEL SPEEDS*

	Surface Feet per Minute
Cylindrical grinding	5,500– 6,500
Internal grinding	2,000– 6,000
Snagging, offhand grinding	5,000– 6,000
Snagging, rubber wheels	9,000–10,000
Surface grinding	4,000– 5,000
Knife grinding	3,500– 4,000
Hemming cylinders	2,100– 2,400
Wet-tool grinding	5,000– 6,000
Cutlery wheels	4,000– 5,000
Rubber and elastic cutting-off wheels	9,000–10,000

* The higher speed is recommended only for the larger wheels.

2. Work Speed.—In machine grinding, speed of work exerts a very pronounced effect on the grinding wheel and hence has to be allowed for in grinding-wheel selection. In general, fast work speed, whether the operation be cylindrical, surface or internal grinding, tends to wear the wheel out faster than slower work speed. This is not necessarily a drawback to good grinding practice, but it must be understood to be properly controlled.

Wheel wear is dependent on the ratio of the surface wheel speed to the surface work speed. The higher the ratio the less work the wheel is required to do in a given amount of time, hence the wheel naturally wears at a slower rate. If the ratio is decreased by increasing the work speed the wheel will be required to do more work in a given time and will wear faster.

In general, the longer the arc of contact in precision grinding operations, the faster should be the speed of the work, in order to have the wheel cut properly.

In hand grinding, the rate at which the work is forced against the wheel or the method of applying the work exerts an influence on grade selection. The harder the grinding wheel is forced, the harder should be the wheel if abrasive economy is to be expected.

3. Condition of the Grinding Machine.—A grinding wheel is a refined tool (as is a milling cutter) and cannot work to good advantage on a machine in poor repair or not properly set up. In such cases allowances must be made at least in the selection of the grade of the wheel. Spindles loose in their bearings necessitate the use of very much harder wheels than would be used under normal conditions. Insecure or shaky foundations cause no end of trouble in grinding, because hard grades have to be employed to overcome the tendency of the wheel to wear rapidly, and thus cutting qualities are sacrificed.

4. Personal Factor or Skill of the Workman.—The workman's knowledge of the tool he is using and its limitations is an important factor in the use of grinding wheels, just as much as in the use of other refined tools. It has been found that on hand grinding it is possible for grinding costs to vary 100 per cent on the same work and with the same kind of a machine in the same factory, due to the difference in the man's methods of applying the work to the wheel. Even in machine grinding, the operator can vary the results and grinding costs by his methods of handling the machine.

1. Factors affecting the selection of the abrasive:

A. Physical properties of the material to be ground.....

- Use aluminous abrasive grinding wheels for materials of high tensile strength:
  - Carbon steels
  - Alloy steels
  - High-speed steels
  - Annealed malleable iron
  - Wrought iron
  - Tough bronzes
  - Tungsten, etc.
- Use silicon carbide grinding wheels for materials of low tensile strength:
  - Gray iron
  - Chilled iron
  - Brass and bronze
  - Aluminum and copper
  - Marble
  - Granite
  - Pearl
  - Rubber
  - Leather, etc.

2. Factors affecting the selection of the grit:

A. Amount of material to be removed..... — Use coarse wheels for fast removal of stock.

B. Finish desired..... — Use fine grain for fine finish.

C. Physical properties of material to be ground..... — Use coarse grain for ductile materials and finer grain for hard, dense or brittle materials.

3. Factors affecting the selection of the grade (degree of hardness):

A. Physical properties of the material to be ground..... — Use hard wheels on soft materials and *vice versa*.

B. Arc of contact	The shorter the contact, the harder the wheel should be.
C. Wheel speed and work speed	The higher the ratio of wheel speed to work speed the softer the grade should be and *vice versa*.
D. Condition of grinding machine	Machines in poor condition require harder wheels than machines in good condition.
E. Skill of operator	Skilful operator can use softer wheels than unskilled man—softer wheels mean more economical production.
	Piece-work grinding usually calls for harder wheels than day work.

4. Factors affecting the selection of the process:

A. Dimensions of wheel	Wheels subjected to bending strains should be made by elastic or rubber process.
	Extremely thin abrasive saws must be made by the elastic or rubber process.
	Wheels over 36-inch diameter are usually made by the silicate process.
B. Rate of cutting	Use vitrified wheels for most rapid cutting at speeds under 6,500 s.f.p.m.; rubber wheels at higher speed.
C. Finish desired	Use elastic or rubber wheels for highest finish, where rapid production is not a factor.
	Use silicate wheels to replace sandstones on cutlery, etc.

Grinding-Wheel Recommendations

A grain and grade list such as this reaches its maximum usefulness only after its purpose is familiar to the user. The following table lists many of the common grinding operations. The column "First

selection" lists wheels that should be tried first. The wheel speeds on page 337 should be used and the wheels of a size commonly used for the work, with the machines in good operating condition.

ABBREVIATIONS USED IN THE FOLLOWING TABLE

SiC	Silicon carbide abrasive
Al	Aluminous abrasive
Vit	Vitrified process
Sil	Silicate process
Rub	Rubber process
Elas	Elastic process

The letters V and S placed before the word "elastic" indicate that the wheels are made of special elastic bonds.

Grinding wheels are sometimes made of a combination of grains and are designated as, for example, 24 combination. A combination wheel with a mixture of fine, coarse and medium grain sizes has a different cutting action from a straight-grained wheel and is desirable for certain operations, particularly cylindrical grinding. Such wheels are designated by C, as 24C-K.

GRADES OF NORTON GRINDING WHEELS

	Vit.	Sil.	Elas.	Rubber
Very soft	G	F G	$\frac{1}{2}$	
Soft	H	H	1	
	I	I	$1\frac{1}{2}$	
	J	J	2	
	K	K	$2\frac{1}{2}$	
Medium	L	L	3	R3
	M	M	4	R4
	N	N		
	O	O	5	R5
Hard	P	P		
	Q	Q		R7
	R	R		
	S	S		R8
	T	T		
Very hard	U			
	W			R9
	Z			

The majority of the wheel manufacturers employ the above system of grading for vitrified wheels. There are a few exceptions, as the Carborundum Co. and the Safety Emery Wheel Co. The former utilize the alphabet in the reverse manner, that is, the hardest wheel is grade D and the softest grade U.

TABLE OF GRINDING WHEEL RECOMMENDATIONS ON THE BASIS OF NORTON GRAIN AND GRADE SYSTEM

Work and Operation	Abrasive and Process	First Selection	
		Grain	Grade
Aluminum:			
Cylindrical	SiC Vit. Al. Elas.	40	J
Surface (cups and cylinders)	Al. Vit.	24	I
Internal	SiC Elas.	30	1½
Snagging	Al. Elas.	36	5
Armatures (laminations):			
Cylindrical	Al. Vit.	36	I
Axes (soft-steel):			
Edging	Al. Vit.	20	U
Siding	Al. Vit.	36	R
Axles	Al. Vit.	46	L
Balls	Al. Vit. from 36-Z to 180-Z according to size, hardness and finish		
Balls (hard-large):			
Final finishing	Al. Vit.	XF	Z
Balls (hard-small):			
Final finishing	SiC Vit.	XF	Z
Ball races-radial	Al. Sil.	20	J to 70-K Al. Vit.
Finish grooving	Al. Elas.	120	4
Rough and finish grooving:			
Inner race, one operation	Al. Elas.	80	4
Rough and finish grooving in one operation	Al. Rub.	80	R4
Bits (auger):			
Grinding throats	Al. Rub.	36	R8
Fluting	Al. Rub.	70	R8
Brass:			
Cylindrical	SiC Vit.	36	J
Internal	SiC Vit.	36	J
Surfacing (cups and cylinders)	SiC Vit.	24	H
Snagging	SiC Vit.	24	Q
Cutting-off	SiC V-Elas.	36	V6
Broaches:			
Sharpening	Al. Vit. Al. Vit.	46	K
Bronze (hard):			
Cylindrical	Al. Vit.	24C	K
Internal	Al. Vit.	60	J
Snagging	Al. Vit.	24	Q
Cutting off	Al. V-Elas.	36	V6

TABLE OF GRINDING WHEEL RECOMMENDATIONS ON THE BASIS OF NORTON GRAIN AND GRADE SYSTEM—*Continued*

Work and Operation	Abrasive and Process	First Selection	
		Grain	Grade
Bushings (hardened-steel):			
Cylindrical	Al. Vit.	46	K
Internal	Al. Vit.	46	K
Centerless (roughing)	Al. Vit.	60	L
Centerless (finishing)	Al. Elas.	120	4
Bushings (cast-iron):			
Cylindrical	SiC Vit.	36	J
Internal	SiC Vit.	36	J
Cams (rough forging):			
Roughing	Al. Vit.	30	P
Cams (hardened-steel):			
Finishing (vitrified wheels)	Al. Vit.	24C	K
Finishing (elastic wheels)	Al. Vit. Al. Elas.	46	3
Cam rollers (hardened-steel)	Al. Vit.	24C	M
Car wheels (chilled-iron)	SiC Vit.	16	Q
Car wheels (steel)	Al. Vit.	20	P
Car wheels (Manganese steel)	Al. Vit.	16	Q
Carbon (soft):			
Cutting off	SiC Rub.	16	R8
Carbon (hard, round, small):			
Cutting off	SiC V-Elas.	60	V_5
Carbon (hard, round, large):			
Cutting off	SiC Rub.	14	R8
Cast iron:			
Cutting off	SiC V-Elas.	36	V_7
Cylindrical	SiC Vit.	36	J
Internal	SiC Vit.	36	J
Surfacing (cups and cylinders)	SiC Vit.	14	H
Surfacing (straight wheels)	SiC Vit.	30	J
Snagging	SiC Vit.	20	S
Chasers (thread):			
Surfacing	Al. Vit.	46	J
Grinding throats	Al. Elas.	60	3
Chilled iron:			
Snagging	SiC Vit.	24	S
Surfacing (cups and cylinders)	SiC Vit.	20	I
Surfacing (straight wheels)	SiC Vit.	36	I
Cylindrical (see *Rolls*)			
Chisels:			
Surfacing (cups and cylinders)	Al. Elas.	46	5
Edging (cups and cylinders)	Al. Vit.	60	M
Sharpening	Al. Vit.	46	M

TABLE OF GRINDING WHEEL RECOMMENDATIONS ON THE BASIS OF NORTON GRAIN AND GRADE SYSTEM—*Continued*

Work and Operation	Abrasive and Process	First Selection	
		Grain	Grade
Commutators:			
Roughing (wheels)	SiC Elas. Al. Elas.	46	$2\frac{1}{2}$
Finishing (wheels)	SiC Elas. Al. Elas.	80	2
Both operations (wheels)	SiC Elas.	60	3
Roughing (bricks)	Al. Elas.	80	$2\frac{1}{2}$
Finishing (bricks)	Al. Elas.	120	$1\frac{1}{2}$
Connecting rods:			
Internal	Al. Vit.	60	K
Surfacing (cups and cylinders)	Al. Vit.	30	I
Copper:			
Cylindrical (also see *Rolls*)	SiC Elas.	70	$1\frac{1}{2}$
Cutting off	SiC Rub.	24	R8
Surfacing (cups and cylinders)	SiC Vit.	14	H
Crankshafts (pins and bearings):			
Roughing	Al. Vit.	36	Q
Finishing	Al. Vit.	50	O
Snagging (for balancing)	Al. Vit.	20	R
Cutter sharpening machine	Al. Vit.	46	K
Cylinders (gas engine):			
Internal (new cylinders, wheels)	SiC Vit.	36	H
Regrinding (wheels)	SiC Vit.	36	H
Honing (new cylinders, sticks)	SiC Vit.	180	M
Rehoning (sticks, roughing)	SiC Vit.	60	L
Rehoning (sticks, finishing)	SiC Vit.	180	M
Dies (forging):			
Cleaning	Al. Vit.	60	P
Dies (threading):			
Chamfering (cone wheel)	Al. Vit.	80	P
Drills:			
Cutting off	Al. S-Elas.	46	S5
Cylindrical	Al. Vit.	50	N
Centerless:			
Roughing	Al. Vit.	80	L
Finishing	Al. Elas.	120	5
Precision sharpening	Al. Vit.	46	L
Point thinning	Al. Elas.	50	2
Forgings:			
Snagging	Al. Vit.	20	R
Frogs and switches:			
Surfacing	Al. Vit.	14	R

TABLE OF GRINDING WHEEL RECOMMENDATIONS ON THE BASIS OF NORTON GRAIN AND GRADE SYSTEM—*Continued*

Work and Operation	Abrasive and Process	First Selection	
		Grain	Grade
Gages:			
Cylindrical	Al. Vit.	80	K
Gages (U. S. thread, coarse pitch):			
Grinding threads	Al. Vit.	120	K
Gages (U. S. thread, fine pitch):			
Grinding threads	Al. Vit.	200	M
Gears (hardened-steel):			
Form precision grinding	Al. Vit.	50	K
Generative precision grinding	Al. Vit.	60	J
Internal	Al. Vit.	46	K
Surfacing (cups and cylinders)	Al. Vit.	30	H
Surfacing (straight wheels)	Al. Vit.	50	I
Glass (lenses):			
Edging	Al. Vit.	200	M
Surfacing (torics)	Al. Vit.	100	N
Guide bars:			
Surfacing (segments or cylinders)	Al. Vit.	16	M
Surfacing (straight wheels)	Al. Vit.	24	J
Hammers (claw):			
Grinding between claws	Al. Rub.	46	R8
Neck grinding	Al. Vit.	30	P
Knives (molding):			
Offhand sharpening	Al. Vit.	36	M
Knives (machine):			
Sharpening	Al. Sil.	36	J
Knives (paper):			
Sharpening	Al. Sil.	36	J
Knives (pocket):			
Machine surfacing	Al. Elas.	60	V6
Offhand surfacing	Al. Sil.	120	O
Links (locomotive):			
Machine grinding	Al. Vit.	46	P
Machine shop grinding:			
General offhand	Al. Vit.	24	Q
Monel metal:			
Cutting off	Al. Rub.	16	R8
	Al. S-Elas.	16	S8
Snagging	Al. Vit.	24	Q
Needles:			
Pointing	Al. Vit.	70	P

TABLE OF GRINDING WHEEL RECOMMENDATIONS ON THE BASIS OF NORTON GRAIN AND GRADE SYSTEM—*Continued*

Work and Operation	Abrasive and Process	First Selection	
		Grain	Grade
Pins:			
Pointing	Al. Vit.	120	R
Pistons (aluminum):			
Cylindrical	SiC Vit. Al. Elas.	36	J
Pistons (cast-iron):			
Cylindrical	SiC Vit.	36	K
Piston pins:			
Cylindrical machine	Al. Vit. Al. Vit.	60	L
Centerless machine:			
Roughing	Al. Vit.	60	L
Finishing	Al. Elas.	120	4
Piston rings (cast-iron or semi-steel):			
Cylindrical	SiC Vit.	36	K
Surfacing roughing (cylinders)	SiC Vit.	20	J
Surfacing (straight wheels)	Al. Vit.	50	N
Internal (offhand)	SiC Vit.	20	Q
Piston rods (locomotive):			
Cylindrical	Al. Vit.	24C	L
Pulleys (cast-iron):			
Cylindrical	SiC Vit.	30	J
Rough with pulley grinder: (Cylinder wheel)	SiC Vit.	24	I
Finish with pulley grinder: (Cylinder wheel)	SiC Elas.	70	2
Rails (welds):			
Surfacing:			
Wheels	Al. Vit.	20	O
Bricks	Al. Vit.	24	N
Razors:			
Concaving	Al. Vit.	60	O
Safety sharpening	Al. Vit.	XF	J
Reamers:			
Backing off	Al. Vit.	46	K
Cylindrical	Al. Vit. Al. Vit.	46	K
Fluting	Al. Rub. Al. S-Elas.	80	R8
Roller-bearing cups:			
Cylindrical	Al. Vit.	60	J
Internal	Al. Vit.	60	K

TABLE OF GRINDING WHEEL RECOMMENDATIONS ON THE BASIS OF NORTON GRAIN AND GRADE SYSTEM—*Continued*

Work and Operation	Abrasive and Process	First Selection	
		Grain	Grade
Rollers for bearings:			
Cylindrical	Al. Vit.	100	O
Rolls (brass or copper):			
Cylindrical (roughing)	SiC Elas.	46	2
Cylindrical (finishing)	SiC Vit.	100	I
Rolls (cast-iron):			
Cylindrical (roughing)	SiC Vit.	30	K
Cylindrical (finishing)	SiC Vit.	80	J
Rolls (chilled-iron):			
Roughing	SiC Vit.	36	L
Finishing	Al. Elas.	70	1½
Rolls (hard-rubber):			
Cylindrical (roughing and finishing)	SiC Vit.	36	K
Rolls (soft-rubber):			
Cylindrical (roughing and finishing)	SiC Vit.	36	K
Sad irons:			
Surfacing (cups and cylinders)	SiC Vit. Al. Sil.	20	H
Surfacing (offhand)	SiC Vit.	16	N
Safes:			
Snagging	Al. Vit.	16	Q
Surfacing	Al. Vit.	20	O
Saws (circular):			
Gumming	Al. Vit.	46	M
Saws (metal-cutting):			
Gumming	Al. Vit.	60	P
Spline shafts:			
Cylindrical	Al. Vit.	46	K
Surfacing splines	Al. Vit.	46	K
Springs (leaf):			
Grinding eyes	Al. Vit.	24	Q
Chamfering	Al. Vit.	24	Q
Steel castings (low-carbon):			
Snagging (floor stand)	Al. Vit.	14	R
Snagging (portable machine)	Al. Vit.	24	R
Steel castings (manganese):			
Snagging (swing frame)	Al. Vit.	14	R
Snagging (floor stand)	Al. Vit.	16	Q
Steel (hardened):			
Cylindrical	Al. Vit.	24C	K
Surfacing (cups and cylinders)	Al. Sil.	30	G

TABLE OF GRINDING WHEEL RECOMMENDATIONS ON THE BASIS OF NORTON GRAIN AND GRADE SYSTEM *Concluded*

Work and Operation	Abrasive and Process	First Selection	
		Grain	Grade
Surfacing (straight wheels)	Al. Vit.	36	H
Cutting off	Al. S-Elas.	46	S4
Internal	Al. Vit.	60	J
Steel (soft):			
Cylindrical	Al. Vit.	24C	M
Surfacing (cups and cylinders)	Al. Vit.	16	J
Surfacing (straight wheels)	Al. Vit.	36	K
Cutting off	Al. Rub.	36	R8
Internal grinding	Al. Vit.	46	L
Steel (high-speed):			
Surfacing (cups and cylinders)	Al. Sil.	46	G
Surfacing (straight wheels)	Al. Vit.	46	G
Cutting off	Al. Elas.	60	4
Internal	Al. Vit.	46	J
Stellite:			
Surfacing (cups and cylinders)	Al. Sil.	46	G
Surfacing (straight wheels)	Al. Vit.	46	G
Cutting off	Al. Elas.	46	5
Offhand tool grinding	Al. Vit.	46	M
Taps:			
Grinding relief	Al. Vit.	60	N
Fluting	Al. S-Elas.	46	S9
Threading	Al. Vit.	150	L
Shanks (cylindrical)	Al. Vit.	80	L
Tools (lathe and planer):			
Light (offhand	Al. Vit.	46	N
Heavy (offhand)	Al. Vit.	30	O
Using large wheels	Al. Sil.	24	P
Automatic (cup wheel)	Al. Vit.	24	L
Automatic (straight wheel)	Al. Sil.	46	M
Tungsten rods:			
Cutting off	Al. Rub.	90	R9
Valves (automobile):			
Grinding seats	Al. Vit.	60	N
Cylindrical grinding stems	Al. Vit.	46	M
Welds:			
Cleaning	Al. Vit.	24	Q
Worms:			
Grinding threads	Al. Vit.	36	K
Wrought iron:			
Snagging	Al. Vit.	20	R

Comparative Grading List

The list below gives the comparative gradings of the leading grinding-wheel manufacturers issued by Carborundum Co.

Carborundum	Norton	Abrasive	American	Safety	Sterling	Chicago	Vitrified	Courtland	Star	Hampden	Detroit	Carborundum Elastic	Norton Elastic	Abrasive Elastic	American Silicate	American Elastic	Detroit Elastic
	Z						G			Z	Z+4						
	Y		Z							Y	Z+3						
	X	Z	W							X	Z+2						
	W	W	V		6		F3			W	Z+1						
D	V	T	U	D	5¾		F2			V	Z						
	U		T	E2½						U							
	T		S	E2¼	5½					T	Y				7		
	S			E2						S							
E	R	S	R	E	5¼			R		Q	X						
F		R		N1¾	5		F1		Z						6		
					4¾						W						
				N½	4½				Y							7E	
					4¼												
G+	Q	Q+	Q	N¼	4	F		Q	G1	P	V	1	7	7E	5		7
G		Q		N	3½				G		U						
									F2	O							
H+		P+		O½	3½	E1				N	T		6	6E		6E	6
H	P		P	O¼		E	F	P	F1	M	S	2			4½		
				O													
I+		P			3½	D3	E3		F	L	R		5	5E		5E	
				1¾			E2										5
				1½												4½E	
				1¼					D2						4E		
I	O	O+	O	1	3	D2	E1	O		K	Q		4		4	4E	4
				P¾			E		D1								
				P½			D3			J							
				P¼	2¾	D	D2		D								
J	N	O	N	P	2½			N		I	P	3	3	3E	3½	3½E	3
							D1		C2								
K	M	N	M	M¾	2¼	C1	D	M	C	H	O	4		2½E	3	3E	
				M½			C3										
							C2			G			2½	2E			2½
L	L	M+	L	M¼	2¼		C1	L	B2	F	N				2½	2½E	
M	K	M	K	M	2	C	C	K	B1	E	M	5		1¾E	2		
N		L+		A3	1¾	B2					L	6	2	1½E		2E	2
				A2													
O	J		J	A1	1½	B1		J	B		K				1½	1½E	
P		L	I	A	1¼	B			2H		J			1¾E	1	1E	
Q		K+		H½							I		1½				1½
R	I			H	1	A1	B				H	7		1E			
S		K		C½		A			W		G	8		½E			
T	H	J	H	C							F	9			¾	¾E	
U	G	I	G								E	10	1	½E	⅔	⅔E	1
V		H									D						
W	F										C	11		¼E			
X		G									B						
Y											A						
Z	E																

STANDARD GRINDING WHEELS

Adopted by the Grinding Wheel Mfr's Assoc. in 1925, and greatly reducing the number of wheels to be carried in stock. Fig. 1 shows the 12 faces adopted. The wheel shapes are shown in Figs. 2 and 3.

TABLE 1.—SIZES OF MACHINE SPINDLES FOR DIFFERENT WHEELS

Diameter in Inches	Thickness of Wheel in Inches																				
	¼	⅜	½	⅝	¾	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	4	4½	5
6	½	½	½	½	½	½	½	½	½	½	½	½	½	½	½	½	1	1	1
7	½	½	½	½	½	½	½	½	½	½	½	½	½	1	1	1	1	1	1
8	½	½	½	½	½	½	½	½	½	1	1	1	1	1	1	1	1¼	1¼	1¼
9	½	½	½	½	½	½	½	½	¾	1	1	1	1	1¼	1¼	1¼	1¼	1¼	1¼
10	½	½	½	½	½	½	½	¾	1	1	1	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½
12	½	½	½	½	½	1	1	1	1	1	1	1¼	1¼	1¼	1¼	1½	1½	1½	1½
14	½	½	½	½	1	1	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½	1½
16					1¼	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½	1½	1½	1½
18					1¼	1¼	1¼	1½	1½	1½	1½	1½	1½	1½	1½	1½	1¾	1¾	1¾
20						1½	1½	1½	1½	1½	1½	1½	1¾	1¾	1¾	1¾	1¾	1¾	1¾
24						1½	1½	1½	1½	1½	1½	1¾	1¾	2	2	2	2	2	2
26							1½	1½	1½	1½	1¾	1¾	2	2	2	2	2	2½	2½
30								1¾	1¾	2	2	2	2	2	2½	2½	2½	2½	2½
36									2	2	2½	2½	2½	2½	2½	2½	2½	3	3

No user of wheels should operate on any machine of given spindle diameter a wheel of larger diameter or greater thickness than specified in the following table.

The proper size of spindle to use for any wheel from 6 to 36 inches in diameter and from ¼ to 5 inches thick, is shown in Table 1. Standard internal grinding wheels for new installations are given in Table 2.

TABLE 2.—STANDARD INTERNAL GRINDING WHEELS
(Dimensions in Inches)

Wheel Diameter	Arbor	Wheel Diameter	Arbor
¼	⅛	1½	⅜
⅜	⅛	1¾	⅜
½	1/16	2	½
⅝	1/16	2	⅝
¾	¼	2¼	⅝
⅞	¼	3	¾
1	¼	3½	⅞
1	⅜	4	1
1¼	⅜	4	1¼

Thicknesses $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2 inches.

Cylinder grinding wheels are:

Diameters, $2\frac{1}{2}$, $2\frac{3}{4}$, 3, $3\frac{1}{2}$, 4, $4\frac{1}{2}$.

Thicknesses, $\frac{3}{4}$, 1, $1\frac{1}{4}$.

Arbors, $\frac{7}{8}$, $1\frac{1}{4}$.

Recess, $1\frac{3}{4} \times \frac{1}{4}$ for $\frac{7}{8}$ hole. $2\frac{1}{4} \times \frac{1}{4}$ for $1\frac{1}{4}$ hole, all dimensions being in inches.

Cutting-off wheels are made in 6-, 7-, 8- and 12-inch diameters. The 6-, 7- and 8-inch are made both $\frac{1}{16}$ and $\frac{1}{8}$ inch thick. The 12-inch wheel is made $\frac{3}{32}$ and $\frac{1}{8}$ inch thick.



STANDARD DIMENSIONS OF PROTECTION FLANGES
(All Dimensions in Inches)

A Diameter of Wheel	*B* Minimum Outside Diameter of Flanges	*C* Radial Width of Bearing Surface		*D* Minimum Thickness of Flange at Bore	*E* Minimum Thickness of Flange at Edge of Recess
		Minimum	Maximum		
1	$\frac{3}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$
2	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{32}$
3	1	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{32}$
4	$1\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{1}{8}$
5	$1\frac{1}{2}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
6	2	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
8	3	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
10	$3\frac{1}{2}$	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{4}$
12	4	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{5}{16}$
14	$4\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{5}{16}$
16	$5\frac{1}{2}$	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{5}{16}$
18	6	$\frac{1}{2}$	1	$\frac{5}{8}$	$\frac{3}{8}$
20	7	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{8}$
22	$7\frac{1}{2}$	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{7}{16}$
24	8	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{7}{16}$
26	$8\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{2}$
28	10	$\frac{7}{8}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$
30	10	$\frac{7}{8}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{8}$
36	12	1	2	$\frac{7}{8}$	$\frac{3}{4}$

Tapered protection flanges shall always be used with tapered wheels having the same degree of taper, which should be at least $\frac{1}{8}$ inch per foot for each flange.

Recommended and Maximum Speeds.—The speeds shown in column *A* of the following table should not be exceeded, except on recommendation of the wheel manufacturer, and in no case should speeds shown in column *B* be exceeded.

Note.—Some manufacturers are willing to recommend higher speeds for precision grinding and on rubber-bonded wheels.

	Wheel Classification	*A* Standard Peripheral Speed, Feet per Minute	*B* Maximum Peripheral Speed, Feet per Minute
Vitrified and Silicate Wheels	Cup and cylinder wheels when used for rough grinding, on bench, floor, portable machines, etc.	4,500	5,500
	All other vitrified and silicate bonded wheels	5,000	6,500
Rubber and Shellac Bonded Wheels	Rubber-bonded wheels	8,000	10,000
	Shellac-bonded wheels used for cutting off	8,000	10,000
	All other shellac-bonded wheels	5,000	6,500

The vast number of abrasive wheels in use upon the class of machines commonly known as bench and floor grinders, grinding wheel stands, emery grinders, etc., and which are so generally in service at various points about the machine shop, blacksmith shop and foundry, makes it desirable that something should be said here in reference to the best methods of mounting wheels on such apparatus.

In the first place, the machine itself should be of rigid construction, with spindle of ample proportions; the bearings should be well fitted; and kept well oiled so that the arbor will not become overheated and, by expanding, break the wheel; and the machine should be securely fastened on substantial foundations not only to insure safety but in order to secure better results with the wheel.

Protection flanges should always be used on wheels 6 inches and larger, especially where not provided with protection hoods, chucks or bands.

The flanges should be recessed at least $\frac{1}{16}$ inch, and they should have a true bearing at the outer edge as shown. (See table on page 350 for sizes.) The inner flange should never be loose but in

all cases should be fixed on the spindle. The bore in the outer flange should not be more than 0.002 inch larger than the spindle. Wheels must not be allowed to run when held only by a nut in place of a flange, as the nut is liable to crawl and cause accident.

Compressible washers of pulp or rubber, slightly larger than the flanges, should be used between the flanges and the wheel as shown at *A*, Fig. 8. These distribute the pressure evenly when the flanges are tightened, by taking up any imperfections in the wheel or flanges.

The hole in the wheel bushing should be 0.005 inch larger than standard size spindles. This permits the wheel to slide on the spindle without cramping and insures a good fit not only on the spindle but against the inside flange, which is essential.

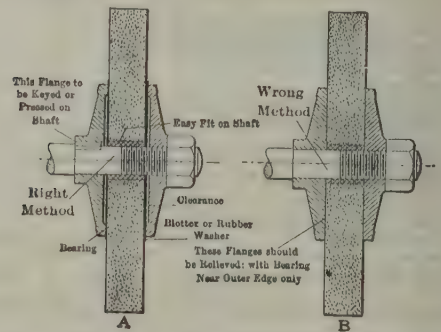


FIG. 8.—Right and Wrong Way to Mount Wheels

The flanges should be tightened only enough to hold the wheel firmly, thus avoiding unnecessary strain.

General Suggestions

HANDLE all wheels with the greatest care in unpacking, storing, delivering, etc. Wheels are frequently cracked by rough usage before they are placed on the grinding machine. The man in charge of the storeroom should inspect each wheel before giving it out to the workman.

Wheels should be stored in a dry place.

A wheel used in wet grinding should not be left overnight partly immersed in water.

All new wheels shall be run at full operating speed for at least 1 minute before applying work, during which time the operator shall stand at one side.

When mounting wheels the nut should not be screwed up too tight; it should be set up only enough so that the flanges hold the wheel firmly.

Keep all rests adjusted close to the wheel so that work cannot be caught.

Avoid heavy pressure of the work on the wheel when grinding. Work should not be forced against a cold wheel, but applied gradually, giving the wheel an opportunity to warm and thereby minimize the chance of breakage. This applies to starting work in the morning in cold rooms, and to new wheels which have been stored in a cold place.

Keep the wheel true by dressing frequently. Wheels should be occasionally tested for balance, and rebalanced if necessary.

If a wheel vibrates, there is something wrong. It should be trued up and the boxes should be rebabbitted after the journals are trued up.

Never hack a wheel; it is unnecessary and dangerous.

Use wheel guards wherever possible (see page 357).

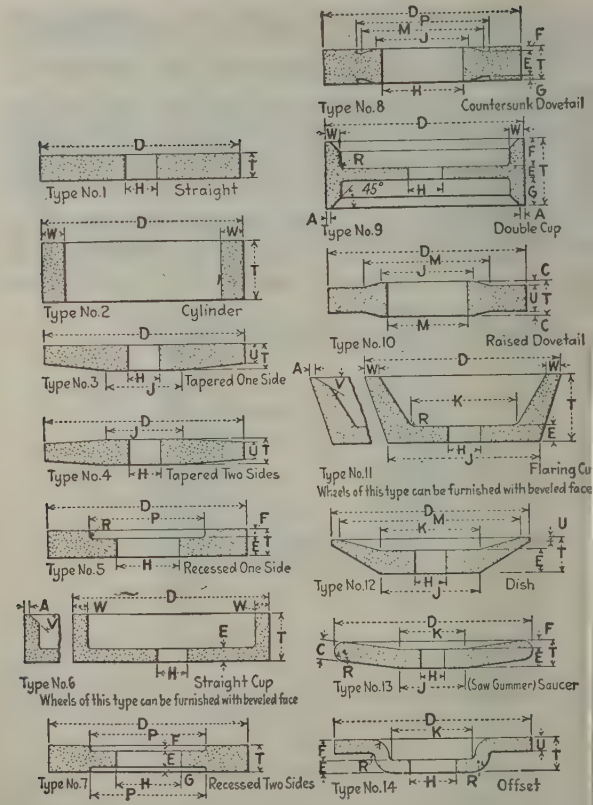

Type No.1 Straight
Type No.2 Cylinder
Type No.3 Tapered One Side
Type No.4 Tapered Two Sides
Type No.5 Recessed One Side
Type No.6 Straight Cup
Wheels of this type can be furnished with beveled face
Type No.7 Recessed Two Sides
Type No.8 Countersunk Dovetail
Type No.9 Double Cup
Type No.10 Raised Dovetail
Type No.11 Flaring Cup
Wheels of this type can be furnished with beveled face
Type No.12 Dish
Type No.13 (Saw Gummer) Saucer
Type No.14 Offset

FIG. 9.

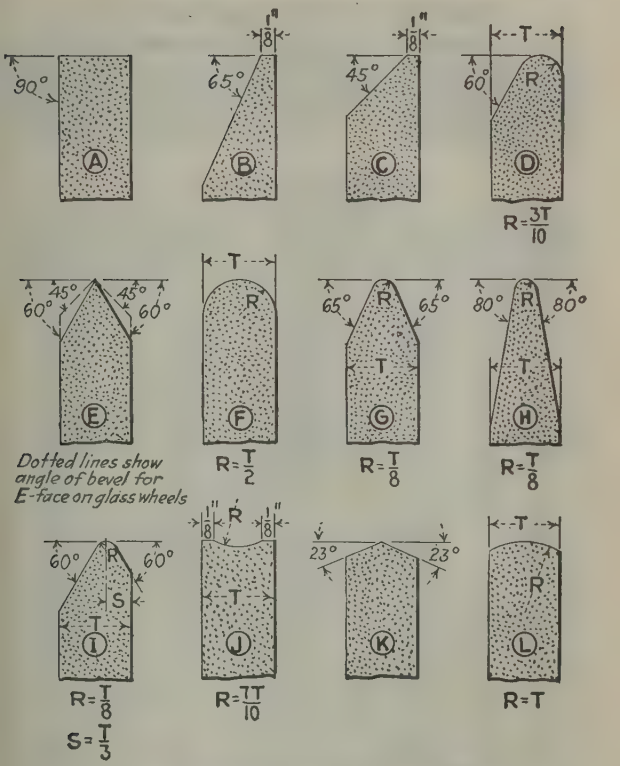


FIG. 10.—Standard Faces of Grinding Wheels

Speed Tables, Rules for Surface Speeds, etc.

THE table below gives the number of revolutions per minute at which grinding wheels of diameters ranging from 1 to 60 inches must be operated to secure peripheral velocities of 4,000, 5,000, 5,500 and 6,000 feet per minute. Ordinarily a speed of 5,000 feet per minute is employed, though sometimes the speed is somewhat lower or higher for certain cases.

GRINDING WHEEL SPEEDS

Diameter Wheel in Inches	R.p.m. for Surface Speed of 4,000 Feet	R.p.m. for Surface Speed of 5,000 Feet	R.p.m. for Surface Speed of 5,500 Feet	R.p.m. for Surface Speed of 6,000 Feet
1	15,279	19,099	21,000	22,918
2	7,639	9,549	10,500	11,459
3	5,093	6,366	7,350	7,639
4	3,820	4,775	5,250	5,730
5	3,056	3,820	4,200	4,584
6	2,546	3,183	3,500	3,820
7	2,183	2,728	3,000	3,274
8	1,910	2,387	2,600	2,865
10	1,528	1,910	2,100	2,292
12	1,273	1,592	1,750	1,910
14	1,091	1,364	1,500	1,637
16	955	1,194	1,300	1,432
18	849	1,061	1,150	1,273
20	764	955	1,050	1,146
22	694	868	950	1,042
24	637	796	875	955
26	586	733	800	879
28	546	683	750	819
30	509	637	700	764
32	477	596	650	716
34	449	561	620	674
36	424	531	580	637

The exact speed at which any specified wheel should be run depends upon several conditions, such as the type of machine, character of work and wheel, quality of finish desired and various other factors referred to at other places in this book. Wheels are ordinarily run in practice from about 4,000 to 6,000 feet per minute, though in some cases a speed as high as 7,500 feet has been employed. An average speed recommended by most wheel makers is 5000 feet. To allow an ample margin of safety it is recommended that wheel speeds should not exceed 6000 feet per minute.

GRINDING ALLOWANCES FOR VARIOUS LENGTHS AND DIAMETERS

Table 1 shows the practice of the Landis Tool Company, in the material left for grinding. This table covers work up to 12 inches diameter, and lengths to 48 inches.

TABLE 1.—ALLOWANCES FOR GRINDING
(LANDIS TOOL CO.)

Length	3″	6″	9″	12″	15″	18″	24″	30″	36″	42″	48″
Diam.											
½	.010	.010	.010	.010	.015	.015	.015	.020	.020	.020	.020
¾	.010	.010	.010	.010	.015	015	.015	.020	.020	.020	.020
1	.010	.010	.010	.015	.015	.015	.015	.020	.020	.020	.020
1¼	.010	.010	.015	.015	.015	.015	.015	.020	.020	.020	.020
1½	.010	.015	.015	.015	.015	.015	.020	.020	.020	.020	.020
2	.015	.015	.015	.015	.015	.020	.020	.020	.020	.020	.025
2¼	.015	.015	.015	.015	.020	.020	.020	.020	.020	.025	.025
2½	.015	.015	.015	.020	.020	.020	.020	.020	.025	.025	.025
3	.015	.015	.020	.020	.020	.020	.020	.025	.025	.025	.025
3½	.015	.020	.020	.020	.020	.020	.025	.025	.025	.025	.025
4	.020	.020	.020	.020	.020	.025	.025	.025	.025	.025	.030
4½	.020	.020	.020	.020	.025	.025	.025	.025	.025	.030	.030
5	.020	.020	.020	.025	.025	.025	.025	.025	.030	.030	.030
6	.020	.020	.025	.025	.025	.025	.025	.030	.030	.030	.030
7	.020	.025	.025	.025	.025	.025	.030	.030	.030	.030	.030
8	.025	.025	.025	.025	.025	.030	.030	.030	.030	.030	.030
9	.025	.025	.025	.025	.030	.030	.030	.030	.030	.030	.030
10	.025	.025	.025	.030	.030	.030	.030	.030	.030	.030	.030
11	.025	.025	.030	.030	.030	.030	.030	.030	.030	.030	.030
12	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030

Table 2 gives the allowances of the Brown & Sharpe Mfg. Co. in rough turning work for the grinding department. Limit gages of the "snap" type are used, the dimensions in the table covering work up to 2 inches diameter.

TABLE 2.—LIMIT GAGE SIZES FOR LATHE WORK WHICH IS TO BE FINISHED BY GRINDING
BROWN & SHARPE MFG. CO.

Size	Not go on	Go on	Size	Not go on	Go on	Size	Not go on	Go on
	Inches			Inches			Inches	
3/8	0.383	0.387	15/16	0.9455	0.9495	1 1/2	1.508	1.512
7/16	0.4455	0.4495	1	1.008	1.012	1 9/16	1.5705	1.5745
1/2	0.508	0.512	1 1/16	1.0705	1.0745	1 5/8	1.633	1.637
9/16	0.5705	0.5745	1 1/8	1.133	1.137	1 11/16	1.6955	1.6995
5/8	0.633	0.637	1 3/16	1.1955	1.1995	1 3/4	1.758	1.762
11/16	0.6955	0.6995	1 1/4	1.258	1.262	1 13/16	1.8205	1.8245
3/4	0.758	0.762	1 5/16	1.3205	1.3245	1 7/8	1.883	1.8875
13/16	0.8205	0.8245	1 3/8	1.383	1.387	1 15/16	1.9455	1.949
7/8	0.883	0.887	1 7/16	1.4455	1.4495	2	2.008	2.012

MAGNETIC CHUCKS

MAGNETIC chucks have come to be a very necessary part of the equipment of any surface-grinding machine, whether plain or rotary. Before their coming it was customary to bed thin work in wax on the platen of a grinder in order to finish the flat sides. Other flat work had to be held in "fingers" on special fixtures, and on account of their being very thin and easily sprung, it was difficult to secure really accurate work.

The magnetic chuck holds the thinnest pieces of iron or steel firmly, draws down any slight spring in the work and prevents springing when strains are released during the grinding operations.

The chuck face is divided into magnet poles, separated by babbit or other non-magnetic metals, and coils of insulated wire from these into electromagnets when current is applied. For rotary work, the electric current is supplied by brushes running against insulated contact rings on the outside. Current can be supplied from any incandescent lamp socket on a direct current circuit.

Alternating current cannot be used.

A chuck having a face 10 × 14 inches uses about one-half as much power as a 16 candle-power lamp.

Hints for Using Magnetic Chucks

The chucks should not be taken apart.

Nothing but iron or steel can be held on the chucks.

The holding power depends on the amount of work surface in contact with the chuck.

Work can be held on edge by using adjustable back rest.

Very thin work can be held for grinding on the edges by laying it against the back rest and backing it up with a parallel strip.

Thin work will not hold as well as thick work.

In packing a number of small pieces on a chuck at one setting, it is better to separate them a little with strips of non-magnetic material.

Do not plug up the vent holes in the chuck.

Keep water away from the switch, the brushes and the interior of the chuck.

Magnetic chucks do not take the place of all other chucks.

Do not use water on chucks except where they are made for it.

Chucks are usually wound for 110 or 220 volts *for direct current only*.

LAPPING

Lapping may be defined as the process of finishing the surface of a piece of work by means of another piece of material, called a lap, the surface of which is charged with an abrasive.

Laps are roughly divided into three general classes. First, those where the form of the lap makes a line contact with the work, and the work is, if cylindrical, revolved to develop the cylindrical form,

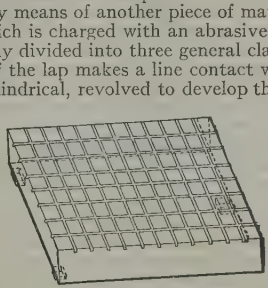


Fig. 11.—A Lapping Plate for Flat Work

or, if straight, in one direction, is moved back and forth under the lap. Second, those which are used for straight surfaces with a full contact on the lap, and third, those which are used for male and female cylindrical surfaces with a full contact on the lap. In all cases the material from which the lap is made must be softer than the work. If this is not so, the abrasive will charge the work and cut the lap, instead of the lap cutting the work.

The first class is used in the place of emery wheels, either where the work is too small to use an ordinary wheel or where a form is to be ground on the work and an emery wheel will not keep its shape. They are usually made of machinery steel and the abrasive used is crushed diamond rolled into the surface. In rolling in the diamond dust the sharp corners of the particles cause them to bed securely into the surface of the lap, and if a good quality of diamond is used, a lap will grind all day without recharging. Oil is used to lubricate the work and carry away the dust from the grinding. If a diamond lap is run dry the particles of diamond tear and raise "burs" in the work, which strip the lap very quickly. The speed should be about two-thirds that for an emery wheel of the same size; for if it is excessive, the lap will wear smooth and glaze instead of cutting. This kind of lap is used mainly in watch and clock shops, and shops making watch tools, sub-press dies, and similar work.

Lapping Flat Surfaces

In lapping flat surfaces, which are usually on hardened steel, a cast-iron plate is used as a lap and a good abrasive. In order that the plate may stay reasonably straight, it should either be quite thick, or else ribbed sufficiently to make it rigid, and in any case it should be supported on three feet, the same as a surface place. For rough work or "blocking down," as it is called, the lap works better if scored with narrow grooves, about ½ inch apart, both lengthways and crossways, thus dividing the plate into small squares, as in Fig. 11. The abrasive is sprinkled loosely on the block, wet with lard oil and the work rubbed on it; care is taken to press hardest on the highest spots. The abrasive and oil get in the grooves, and are continually rolling in and out, getting between the plate and the work and are crushed into the cast iron, thus charging it thoroughly in a short time. About No. 100 or 120 emery is best for this purpose.

After blocking down, or if the work has first been ground on a surface grinder, the process is different. A plain plate is used with the best quality of flour of emery as an abrasive, as the least lump or coarseness will scratch the work so that it will be very hard to get the scratches out. Instead of oil, benzine is used as a lubricant, and the lap should be cleaned off and fresh benzine and emery applied as often as it becomes sticky. The work should be tried from time to time with a straight-edge and care taken not to let the emery run in and out from under the work, as this will cause the edges to abrade more than the center, and will especially mar the corners. After getting a good surface, the plate and work should be cleaned perfectly dry, and then rubbed. The charging in the plate will cut just enough to remove whatever emery may have become charged in the work, take away the dull surface and leave it as smooth as glass and as accurate as it is possible to produce.

Some grind flat work to within 0.0005 inch of size and lap to within 0.0005 inch on a type-metal lap charged with flour emery. The lap is used dry and cleaned with benzine. Crocus powder on a cast-iron lap gives a high polish.

Laps for Holes

In lapping holes various kinds of laps are used, according to the accuracy required, and the conditions under which the work is done. The simplest is a piece of wood turned cylindrical with a longitudinal groove or split in which the edge of a piece of emery cloth is inserted. This cloth is wound around the wood until it fills the hole in the work. This is only fit for smoothing or enlarging rough holes and usually leaves them more out of round and bell-mouthed than they were at first. Another lap used for the same purpose—and which produces better results—is made by turning a piece of copper, brass, or cast iron to fit the hole and splitting it longitudinally for some distance from the end. Loose abrasive is sprinkled over it, with lard oil for a lubricant, and a taper wedge is driven into the end for adjustment as the lap wears.

For lapping common drill bushings, cam rolls, etc., in large quantities, where a little bell-mouthing can be allowed, and yet a reason-

ably good hole is required, a great many shops use adjustable copper laps made with more care than the above. One way of making them is to split the lap nearly the whole length, but leaving both ends solid. One side is drilled and tapped for spreading screws for adjustment. Either one screw half-way down the split may be used or two screws dividing the split into thirds. Another and better means of adjustment is to drill a small longitudinal hole a little over half the length of the lap, enlarge it for half its length, and tap the large end for some distance. This is done before splitting. Into this hole a long screw with a taper point is fitted so that when tightened it tries to force itself into a small hole, thus spreading the lap.

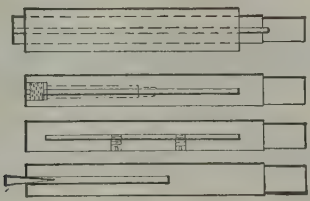


FIG. 12.—Laps for Holes

For nice work there is nothing better than a lead lap. Lead charges easily, holds the abrasive firmly and does not scratch or score the work. It is easy to fit to the work and holds its shape well for light cuts. Under hard usage, however, it wears easily. For this reason, while laps for a single hole or a special job are sometimes cast on straight arbors, where much lapping is done it is customary to mold the laps to taper arbors with means for a slight adjustment. After any extensive adjustment the lap will be out of true and must be turned off. All of these laps, as shown in Fig. 12, are to be held by one end in a lathe chuck, and the work run back and forth on them by hand, or by means of a clamp held in the hand. If a clamp is used care should be taken not to spring the work.

How to Do Good Lapping

THERE are several points which must be taken into consideration in order to get good results in lapping holes. The most important is that the lap shall always fill the hole. If this condition is not complied with the weight of the work and the impossibility of holding it exactly right will cause it to lap out of round, or if it is out of round at the start the lap will be free to follow the original surface. If the lap fits, it will bear hardest on the high spots and lap them off. Next in importance to getting a round hole is to have it straight. To attain this end the lap should be a little longer than the work, so that it will lap the whole length of the hole at once, and not have a tendency to follow any curvature there may be in it. What is known as bell-mouthing, or lapping large on the ends, is hard to pre-

vent, especially if the emery is sprinkled on the lap and the work shoved on it while it is running. The best way to avoid this condition when using cast-iron or copper laps, which do not charge easily, is to put the emery in the slot, near the center of the lap, and after the work is shoved on squirt oil in the slot to float the emery. Then, when the lathe is started the emery will carry around and gradually work out to the ends, lapping as it goes. Where lead is used the emery can be put on where it is desired to have the lap cut and rolled in with a flat strip of iron. It will not come out easily, so will not spread to any extent, and it is possible with a lap charged in this manner to avoid cutting the ends of the hole at all. The work should always be kept in motion back and forth to avoid lumping of the emery and cuttings which will score grooves in the work.

Ring Gage and Other Work

Rings gages are lapped with a lead lap. They are first ground straight and smooth to within .0005 inch of size, and then, when lapped, are cooled as well as cleaned, before trying the plug, by placing them in a pail of benzine for a long enough time to bring them down to the temperature of the room. Some shops leave a thin collar projection from each side around the hole, so that, if there is any bell mouthing, it will be in these collars, which are ground off after the lapping is done.

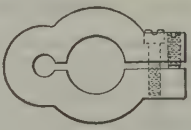


Fig 13.—A Lap for Plugs

Other metals are lapped in this same manner, except that the abrasive is different. Cast iron is lapped with emery, but charges to some extent. This charging can be taken out without changing the work materially by rubbing it by hand with flour of emery cloth. In lapping bronze or brass, crocus and Vienna lime are used. Crocus is used with a cast-iron or lead lap, and the charging is removed by running the work for a few seconds on a hardwood stick which fits the hole. Unslaked Vienna lime, freshly crushed, is used with a lead or hardwood lap, and does not charge. It does a nice job, but is very slow, and is only used in watch factories.

For lapping plug gages, pistons and other cylindrical articles, a cast-iron lap is usually used, split and fitted with a closing and a spreading screw, as shown in Fig. 13. Sometimes, where a very fine finish is required, or where the work is not hardened, the hole is made larger than the work, and a lead ring cast into it.

ADJUSTABLE STEP LAP FOR PLUG GAGES

The step lap, Fig. 14, can be used to advantage for plug gages. It is of gray cast iron, and the end hole *A* adjusted to size. The lap

is used at this hole until it refuses to cut. The plug gage is then entered into hole *B* without changing the adjustment. This hole is used up, and the plug gage is passed to holes *C* and *D*.

As the holes are all made one size, and as the plug gage becomes smaller at each hole, there is less wear on the lap as the plug is passed from hole to hole. The holes retain about the same proportions and save measuring for sizes very often, when rough-lapping the plugs to within 0.0001 inch of finish size. As a finishing lap for size, it requires very few trial measurements with the micrometer or ring gage.

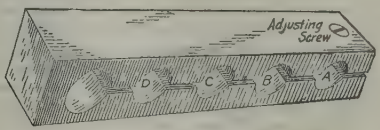


FIG. 14.—Step Lap for Plug Gages

There is a tendency among workmen to use an excessive rotary speed when lapping a plug or ring. A speed that will make the work just comfortably warm to the hand is about right. Speed above this rate has a tendency to bake the oil and abrasive, which is a detriment to smooth and fast cutting.

DIAMOND POWDER IN THE MACHINE SHOP

THE diamond used for this purpose is an inferior grade of diamond, not so hard as the black diamond used for drills and truing emery wheels, and not of the clear and perfect structure to permit it to



FIG. 15



FIG. 16

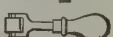


FIG. 17

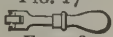


FIG. 18

enter the gem class. Many are mixed black and white, others yellow and some pink; many are clear but flaky. Then there is the small débris from diamond cutting, which is reduced to powder

and sells somewhat cheaper; but some find it more economical to use the above and powder it themselves, as the débris from diamond cutting is of a flaky nature, and does not charge into the lap so well.

Assuming there is 25 carats to reduce to powder, proceed as follows:

Into a mortar, as shown at Fig. 15, place about 5 carats, using an 8-ounce hammer to crush it. It takes from 3 to 4 minutes' steady pounding to reduce it to a good average. Scrape the powder free from the bottom and the sides and empty into one half pint of oil. The oil used is the best olive oil obtainable, and is held in a cup-shaped receptacle that will hold a pint and one half. The 25 carats being reduced to powder, and in the oil, stir it until thoroughly mixed, and allow to stand 5 minutes; then pour off to another dish. The diamond that remains in the dish is coarse and should be washed in benzine and allowed to dry, and should be repounded, unless extremely coarse diamond is desired. In that case label it No. 0. Now stir that which has been poured from No. 0, and allow to stand 10 minutes. Then pour off into another dish. The residue will be No. 1. Repeat the operation, following the table below.

The settlings can be put into small dishes for convenient use, enough oil staying with the diamond to give it the consistency of paste. The dishes can be obtained from a jewelers' supply house.

TABLE FOR SETTLING DIAMOND POWDER

To obtain No. 0— 5 minutes.	To obtain No. 3—1 hour.
To obtain No. 1—10 minutes.	To obtain No. 4—2 hours.
To obtain No. 2—30 minutes.	To obtain No. 5—10 hours.

To obtain No. 6—until oil is clear.

Diamond is seldom hammered; it is generally rolled into the metal. For instance, several pieces of wire of various diameters charged with diamond may be desired for use in die work. Place the wire and a small portion of the diamond between two hardened surfaces, and under pressure roll back and forth until thoroughly charged. No. 2 diamond in this case is generally used. Or one can form the metal any desired shape and apply diamond and use a roll, as Fig. 6, to force the diamond into the metal. This is then a file which will work hard steel, but the moment this diamond file, or lap, is crowded it is stripped of the diamond, and is consequently of no use. It is to be used with comparatively light pressure.

Diamond Laps

COPPER is the best metal. It takes the diamond readily, and retains it longer than other metals; brass next, then bessemer steel. The latter is used when it is wished to preserve a form that is often used.

For sharpening small, flat drills, say 0.008 to 0.100, a copper lap mounted on a taper shank, as in Fig. 16, and charged on the face with

No. 2 diamond, using pressure on the roll, makes a most satisfactory method of sharpening drills. The diamond lasts for a long time if properly used, and there is no danger of drawing the temper on the drill. It is much quicker than any other method of sharpening.

To charge the lap use the roll, Fig. 17, supported on a T-rest pressing firmly against the lap, being careful to have the roll on the center; otherwise instead of charging the lap it will be grinding the roll. The diamond may be spread either on the lap or the roll, and the first charging usually takes twice the amount of diamond that subsequent charging takes. To avoid loss of diamond, wash the lap in a dish of benzine kept exclusively for that purpose. This can be reclaimed by burning the metal with acids, and the diamond can be resettled. A narrower roll Fig. 18 is sometimes used.

For the grinding of taper holes in hard spindles or for position work in hard plates, where holes are too small to allow the use of wheels, No. 1 diamond does the work beautifully. Or if it is wished to grind sapphire centers or plugs as stops, etc., a bessemer lap made in the form of a wheel and charged with diamond on the diameter does the work nicely.

Nos. 5 and 6 diamond are used on boxwood laps, mounted on taper plugs or chucks, and the diamond smeared on with the finger. The lap is run at high speed and used for fine and slow cutting which also gives a high polish.

Other Abrasives for Lapping

The abrasive flours commonly used for lapping have a grain averaging about 0.002 in. in diameter. For fine work the abrasive flours are mixed with oil and allowed to settle. The lighter particles remain in suspension and are poured off. They are graded according to the length of time they float—thus 30 minute abrasive means the particles have taken 30 minutes to settle. Some use water for floating, as oils vary so much in viscosity. The most used lapping lubricants are lard oil, machine oil, kerosene, gasoline, alcohol and turpentine.

Tests of Lapping

Tests made by Knight and Case show that laps charged by rolling cut the fastest and that a lap wet with lubricant cuts approximately twice as fast as a dry lap. The initial rate of cutting does not vary greatly with different abrasives. No advantage was found in using an abrasive coarser than No. 150. The rate of cutting is practically proportional to the pressure, 15 pounds being satisfactory. Laps wear as follows: Cast iron, 1.00; steel, 1.27; and copper, 2.62. In general, copper and steel cut faster than cast iron, but cast iron retains its form better.

The table gives 15 combinations which gave good results in over 60 tests.

GOOD LAPPING COMBINATIONS

Carborundum	Steel lap	Lard oil
Carborundum	Copper lap	Lard oil
Carborundum	Cast lap	Gasoline
Alundum	Copper lap	Soda water
Carborundum	Cast lap	Turpentine
Carborundum	Cast lap	Alcohol
Alundum	Cast lap	Gasoline
Carborundum	Copper lap	Turpentine
Carborundum	Cast lap	Kerosene
Carborundum	Copper lap	Soda water
Carborundum	Steel lap	Machine oil
Alundum	Copper lap	Turpentine
Carborundum	Copper lap	Machine oil
Alundum	Copper lap	Alcohol
Carborundum	Copper lap	Alcohol

REAMER AND CUTTER GRINDING

Reamer Clearances

AFTER constant experimenting for a period of more than a year, the Cincinnati Milling Machine Company succeeded in establishing tables for four styles of reamers for obtaining what they consider to

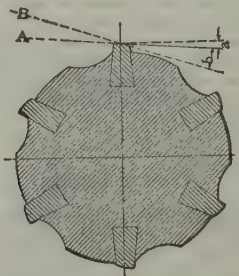


FIG. 19.—Cross-section of Hand Reamer

be the best clearances, the object being to grind clearances on reamers which would ream the greatest number of smooth holes with a minimum amount of wear. The four styles of reamers are as follows: Hand reamers for steel, hand reamers for gray iron and bronze, chucking reamers for gray iron and bronze, chucking

reamers for steel. The company uses adjustable blade reamers almost exclusively, all of which are ground in the toolroom on their universal cutter and tool grinder. High speed steel reamers cling to nickel steel and do not cut it as well as carbon steel.

Fig. 19 is a cross-section of a hand reamer. Two clearance lines, *A* and *B*, are ground on the blades, *a* being the cutting clearance and *b* the second clearance called for in the table. The object of giving the adjustment for the second clearance so minutely is to provide a proper width of land, which equals .025 inch on all hand reamers for gray iron or bronze, and 0.005 inch on hand reamers for steel. Chucking reamers for gray iron and bronze have, in this system, 23-degree beveled ends as shown in Fig. 20, and are provided with two clearances along the blades, for which the settings are



FIG. 20.—Chucking Reamer Blade for Gray Iron and Bronze



FIG. 21.—Chucking Reamer Blade for Steel

given in Table 3. The beveled ends have only one clearance which is equal to the second clearance given in Table 3. Fig. 21 shows a chucking reamer for reaming steel. In these reamers the blades are circular ground to the exact size of hole to be reamed and without clearance, the 45-degree beveled ends only having clearance as given in Table 4. On all reamers of this style the blades are ground from .015 to .020 inch below size half of their length toward the shank end.

In grinding the clearances for the various kinds of reamers as given in Tables 1, 2, and 3, the tooth rest is held stationary on the emery wheel head of the grinder, while in grinding the 45-degree beveled ends on the chucking reamers for steel, the tooth rest is supported from the grinder table and travels with the work. The front end of the hand reamer blades are tapered about 0.004 per inch. The back ends of the blades are also slightly tapered to prevent injuring the holes when backing the reamer out.

REAMER CLEARANCE

Ground with Cup Wheel 3" dia.—Tooth Rest to be Set Central with Grinding Wheel Spindle. Set Work holding Centers above Emery Wheel Center by Amount given below in Tables No. 1–2 and 3.

Set Tooth Rest Below Work Holding Centers. Amount given Below in Table No. 4

TABLE 1 Hand Reamer for Steel Cut'g Clearance Land .006 Wide			TABLE 2 Hand Reamer for Cast Iron and Bronze Cut'g Clearance Land .025 Wide		TABLE 3 Chucking Reamer for Cast Iron and Bronze Cut'g Clearance Land .025 Wide		TABLE 4 Chucking Reamers for Steel Circular Ground	
Size of Reamer	For Cutting Clearance	For Second Clearance	For Cutting Clearance	For Second Clearance	For Cutting Clearance	For Second Clearance	Angle on End of Blade	For Cutting Clearance on Angle
1/4"	.012	.052	.032	.072	.040	.080	45 Degrees	.080
9/32"	.012	.057	.032	.072	.040	.080	45 "	.080
5/16"	.012	.062	.032	.072	.040	.090	45 "	.090
11/32"	.012	.067	.035	.095	.040	.100	45 "	.100
3/8"	.012	.072	.035	.095	.040	.100	45 "	.100
13/32"	.012	.077	.037	.095	.045	.125	45 "	.125
7/16"	.012	.082	.040	.120	.045	.125	45 "	.125
15/32"	.012	.087	.040	.120	.045	.125	45 "	.125
1/2"	.012	.092	.040	.120	.045	.125	45 "	.125
17/32"	.012	.097	.040	.120	.045	.125	45 "	.125
9/16"	.012	.102	.040	.120	.045	.125	45 "	.125
19/32"	.012	.106	.042	.122	.045	.125	45 "	.125
5/8"	.012	.112	.045	.145	.050	.160	45 "	.160
21/32"	.012	.118	.045	.145	.050	.160	45 "	.160
11/16"	.012	.122	.045	.145	.050	.160	45 "	.175
23/32"	.012	.127	.045	.145	.055	.175	45 "	.175
3/4"	.012	.132	.048	.168	.055	.175	45 "	.175
25/32"	.012	.137	.050	.170	.055	.175	45 "	.175
13/16"	.012	.142	.050	.170	.060	.200	45 "	.200
27/32"	.012	.147	.050	.170	.060	.200	45 "	.200
7/8"	.012	.152	.052	.192	.060	.200	45 "	.200
29/32"	.012	.157	.052	.192	.060	.200	45 "	.200
15/16"	.012	.162	.056	.196	.060	.200	45 "	.200
31/32"	.012	.167	.056	.196	.064	.200	45 "	.200
2"	.012	.172	.056	.216	.064	.224	45 "	.225
2 1/32"	.012	.172	.056	.216	.064	.224	45 "	.225
2 1/16"	.012	.172	.059	.219	.064	.224	45 "	.225
2 3/32"	.012	.172	.059	.219	.064	.224	45 "	.225
2 1/8"	.012	.172	.063	.223	.064	.224	45 "	.225
2 5/32"	.012	.172	.063	.223	.064	.224	45 "	.225
2 3/16"	.012	.172	.063	.223	.068	.228	45 "	.230
2 7/32"	.012	.172	.063	.223	.068	.228	45 "	.230
2 1/4"	.012	.172	.065	.225	.072	.232	45 "	.230
2 9/32"	.012	.172	365	.225	.072	.232	45 "	.230
2 5/16"	.012	.172	.065	.225	.075	.235	45 "	.235
2 11/32"	.012	.172	.065	.225	.075	.235	45 "	.235
2 3/8"	.012	.172	.065	.225	.077	.237	45 "	.240

Mount Tooth Rest on Grinding Wheel Head

Mount Tooth Rest on Table of Machine

REAMER CLEARANCE

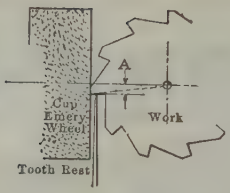
Ground with Cup Wheel 3″ dia.—Tooth Rest to be Set Central with Grinding Wheel Spindle. Set Work holding Centers above Grinding Wheel Center by Amount given below in Tables No. 1–2 and 3.

Set Tooth Rest Below Work Holding Centers. Amount given Below in Table No. 4

TABLE 1 Hand Reamer for Steel Cut'g Clearance Land .006 Wide			TABLE 2 Hand Reamer for Cast Iron and Bronze Cut'g Clearance Land .025 Wide		TABLE 3 Chucking Reamer for Cast Iron and Bronze Cut'g Clearance Land .025 Wide		TABLE 4 Chucking Reamers for Steel Circular Ground	
Size of Reamer	For Cutting Clearance	For Second Clearance	For Cutting Clearance	For Second Clearance	For Cutting Clearance	For Second Clearance	Angle on End of Blade	For Cutting Clearance on Angle
2 1/16″	.012	.172	.065	.225	.077	.237	45 Degrees	.240
2 1/8″	.012	.172	.070	.230	.080	.240	45 "	.240
2 3/16″	.012	.172	.070	.230	.080	.240	45 "	.240
2 1/4″	.012	.172	.072	.232	.080	.240	45 "	.240
2 5/16″	.012	.172	.072	.232	.080	.240	45 "	.240
2 3/8″	.012	.172	.075	.235	.083	.240	45 "	.240
2 7/16″	.012	.172	.075	.235	.083	.243	45 "	.240
2 1/2″	.012	.172	.078	.238	.083	.243	45 "	.245
2 9/16″	.012	.172	.078	.238	.087	.243	45 "	.245
2 5/8″	.012	.172	.081	.241	.087	.247	45 "	.245
2 11/16″	.012	.172	.081	.241	.090	.247	45 "	.245
2 3/4″	.012	.172	.084	.244	.090	.250	45 "	.250
2 13/16″	.012	.172	.084	.244	.090	.250	45 "	.250
2 7/8″	.012	.172	.087	.247	.093	.253	45 "	.250
2 15/16″	.012	.172	.087	.247	.093	.253	45 "	.250
3″	.012	.172	.090	.250	.097	.257	45 "	.255
3 1/16″	.012	.172	.090	.250	.097	.257	45 "	.255
3 1/8″	.012	.172	.093	.253	.100	.260	45 "	.255
3 3/16″	.012	.172	.093	.253	.100	.260	45 "	.255
4	.012	.172	.096	.256	.104	.264	45 "	.260
4 1/16	.012	.172	.096	.256	.104	.264	45 "	.260
4 1/8″	.012	.172	.096	.256	.104	.264	45 "	.260
4 3/16″	.012	.172	.096	.256	.106	.266	45 "	.260
4 1/4″	.012	.172	.096	.256	.106	.266	45 "	.265
4 5/16″	.012	.172	.096	.256	.106	.266	45 "	.265
4 3/8″	.012	.172	.096	.256	.108	.268	45 "	.265
4 7/16″	.012	.172	.096	.256	.108	.268	45 "	.265
4 1/2″	.012	.172	.100	.260	.108	.268	45 "	.265
4 9/16″	.012	.172	.100	.260	.108	.268	45 "	.265
4 5/8″	.012	.172	.100	.260	.110	.270	45 "	.270
4 11/16″	.012	.172	.100	.260	.110	.270	45 "	.270
4 3/4″	.012	.172	.104	.264	.114	.274	45 "	.275
4 13/16″	.012	.172	.104	.264	.114	.274	45 "	.275
4 7/8″	.012	.172	.106	.266	.116	.276	45 "	.275
4 15/16″	.012	.172	.106	.266	.116	.276	45 "	.275
5″	.012	.172	.110	.270	.118	.278	45 "	.275
5 1/8″	.012	.172	.118	.278				

Mount Tooth Rest on Grinding Wheel head

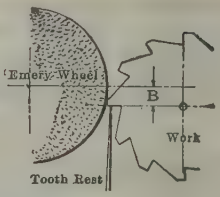
Mount Tooth Rest on Table of Machine



Cup Wheel Clearance Table

For setting tooth rest to obtain 5° or 7° clearance when grinding peripheral teeth of milling cutters with cup-shaped wheel. Tooth rest is set below work centers as at *A*, the distance being found in the table below.

Dia. Cutter Inches	For 5° Clearance A =	For 7° Clearance A =
$\frac{1}{4}$	.011	.015
$\frac{3}{8}$	.015	.022
$\frac{1}{2}$	.022	.030
$\frac{5}{8}$	.028	.037
$\frac{3}{4}$	.033	.045
$\frac{7}{8}$	.037	.052
1	.044	.060
$1\frac{1}{4}$	.055	.075
$1\frac{1}{2}$	.066	.090
$1\frac{3}{4}$	.077	.105
2	.088	.120
$2\frac{1}{4}$	.099	.135
$2\frac{1}{2}$	.110	.150
$2\frac{3}{4}$	.121	.165
3	.132	.180
$3\frac{1}{2}$	.154	.210
4	.176	.240
$4\frac{1}{2}$	.198	.270
5	.220	.300
$5\frac{1}{2}$	.242	.330
6	.264	.360



Disk Wheel Clearance Table

Giving distance *B* for setting work centers and tooth rest below center of wheel spindle to obtain 5° or 7° clearance with wheels of different diameters when grinding with periphery of disk wheel.

Dia. of Wheel Inches	For 5° Clearance B =	For 7° Clearance B =
2	.0937	.125
$2\frac{1}{4}$	.099	.141
$2\frac{1}{2}$	.110	.156
$2\frac{3}{4}$	.125	.172
3	.132	.187
$3\frac{1}{4}$	.143	.203
$3\frac{1}{2}$	.154	.219
$3\frac{3}{4}$	.165	.234
4	.176	.250
$4\frac{1}{4}$	.187	.265
$4\frac{1}{2}$	.198	.281
$4\frac{3}{4}$	.209	.297
5	.220	.312
$5\frac{1}{4}$	.231	.328
$5\frac{1}{2}$	.242	.344
$5\frac{3}{4}$	.253	.359
6	.264	.375
$6\frac{1}{4}$	.275	.390
$6\frac{1}{2}$	.286	.406
$6\frac{3}{4}$	.297	.421
7	.308	.437

CENTERLESS GRINDING

In centerless grinding the work is supported at two points and ground by revolving it between these supports and the wheel.

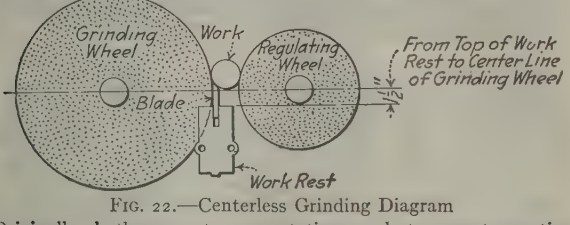


FIG. 22.—Centerless Grinding Diagram

Originally, both supports were stationary, but present practice replaces one support with an abrasive wheel, as in Fig. 22. This is usually a finer wheel and runs at a slower speed. The stationary support should be on the center line of the two wheels, as shown, so that the center of the work will be above this line.

Straight work is fed through automatically between the wheels, the rate of feed depending on the angle between the axis of the regulating or feed wheel, and that of the grinding wheel. The angle varies up to 10 degrees. The supporting guide must be parallel to the line of contact of the work with the regulating wheel. Speed of the regulating machine varies from 11 to 442 r.p.m. in the Cincinnati machines and the standard regulating wheel has a 4-inch face. Both speed and angle affect the quality and quantity of work.

Average roughing cut is from 0.005 to 0.008 inch per pass; finishing cut is from 0.003 to 0.0015 inch per pass. When work is relatively straight but out of round, the regulating wheel should be set at a slight angle, giving a small lap per revolution. When pieces are warped, as from hardening, an angle of 5 or 6 degrees will give a wide lap per revolution and straighten the work. With the proper angle for best results, the speed of regulating or feed wheel should be increased to the limit established by the requirements of accuracy and production.

In form or shoulder grinding the work does not feed through, but is placed between the wheels and the regulating wheel moved in to a stop. This is called "in-feeding."

PROTECTING CUP AND SECTIONAL WHEELS

"Cups, cylinders and sectional ring wheels shall be either protected with hoods, enclosed in protection chucks, or surrounded with protection bands. Not more than one-quarter of the height of such grinding wheels shall protrude beyond the provided protection. Where the thickness of the rim of such wheels is less than 2 inches, the maximum distance which the wheel may protrude beyond the provided protection shall not exceed 1 inch. If the

thickness of the rim is 2 inches or more, the wheel may protrude 2 inches beyond the protection, but shall not exceed this amount.

GUARDS FOR ABRASIVE WHEELS

The safety code prescribes guards for abrasive wheels as shown in Fig. 23. The diagrams gave the amount and the position of the openings for grinding machines of different types.

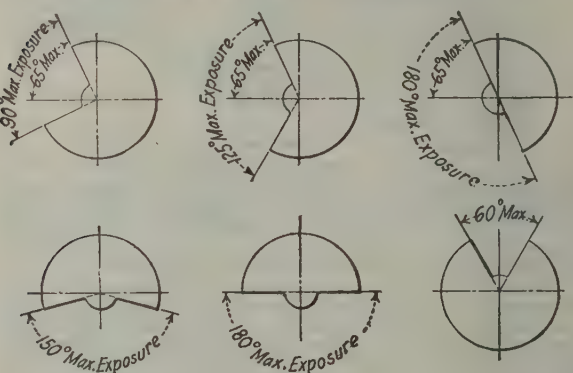


FIG. 23—Wheel Guards

DUST EXHAUST

"Hoods on machines used for dry grinding and other operations where dust is produced shall have provision made for connection to an exhaust system.

"The size of such connections shall be in conformity with the following specified dimensions:

Diameter of Wheel	Medium Diameter of Branch Pipe, Inches
6 inches or less in diameter	3
7 to 16 inches in diameter	4
17 to 24 inches in diameter	5
25 to 30 inches in diameter	6

"A modification of the above requirements will be allowed in the case of narrow wheels used for light work where very little dust is generated and where a smaller pipe will satisfactorily remove it."

POLISHING WHEELS

THERE are many varieties of polishing wheels in use, the principal kinds being known as wooden wheels, compressed wheels, canvas and muslin, sea-horse and felt wheels. For good work, and economy

in abrasive, glue and labor cost, wheels and methods must be selected to suit the work.

A few years ago, the wooden wheel covered with leather and turned to fit the piece to be polished, was universally used. At the present time, the wooden, leather-covered wheel is used largely on flat surfaces and on work where it is necessary to maintain good edges. When this kind of a wheel is made with a double coating of leather, it makes a first-class finishing wheel.

Compressed wheels, or wheels having a steel center are made with surfaces of leather, canvas or linen. Many tool shops are equipped with these wheels exclusively. They answer all purposes and are safer and more economical than wooden wheels.

They are also used largely on cutlery and for polishing chilled plows. The compressed wheel is of strong construction, is very durable and easily kept in balance.

Canvas and muslin wheels are used extensively for polishing stoves, shovels, plows, brass, cast iron and steel. For roughing out and dry fining on irregular pieces, they have proved very satisfactory. They hold the abrasive well and require no washing off as they can be cleaned with a buff stick or an abrasive brick.

Many concerns, such as plow-, shovel- and hoemakers, buy the canvas and muslin and make their own wheels.

Sea-horse wheels are very expensive, most concerns buying the hides and making their own wheels.

Where a high-grade polish is required, there is probably no wheel which can compare with the wheel made of sea horse. They are largely used on guns, pistols and cutlery.

Felt wheels are largely used by stovemakers for finishing surfaces. Bull neck wheels are also used for this purpose.

The felt wheels are made from white Spanish and Mexican felt and are extensively used for finishing on certain classes of work.

Care of Polishing Wheels

Polishing wheels should be kept in perfect balance and running true at all times. A wheel out of balance wastes time, glue and abrasive, and will not do as good work.

The most efficient glue and the best abrasive are the cheapest in the long run.

The glue pots should be kept clean and the glue properly cooked before using.

It is also important to heat the abrasive before applying.

The wheels should be kept properly cleaned and thoroughly covered with the abrasive.

The wheels should be selected for the particular work the same as in grinding and only the wheel best adapted should be used at all times.

Polishing operations are usually divided into three classes: roughing, dry fining, and finishing or oiling.

The abrasives used for roughing usually run from numbers 20 to 80. For dry fining, from numbers 90 to 120. The numbers used for finishing run from 150 to *XF*.

For both roughing out and dry fining, the polishing wheels should be used dry. For finishing, the wheels are first worn down a little and then oil, beeswax, tallow and similar substances are used on the wheel. This, together with the abrasive, brings up a fine finish.

Speed of Buffing Wheels

Wood, leather covered	7,000 ft. per minute
Walrus	8,000 ft. per minute
Rag wheels	7,000 ft. per minute
Hair-brush wheels	12,000 ft. per minute
Ohio grindstone	2,500 ft. per minute
Huron grindstone	3,500 ft. per minute

SAND BLASTING

For cleaning castings and metal work, sand is used under air pressure. A sand that will pass through a No. 8 mesh screen is best for most purposes. Some work requires a very fine sand.

Air pressure varies from 2 to 5 pounds for frosting glass, 15 to 20 pounds for brass and iron castings, 30 to 75 pounds for steel castings, 30 to 35 pounds for steel car and locomotive work. The average pressure is from 20 to 30 pounds.

Sand must be kept dry to prevent clogging nozzles. Pebbles are sometimes used with large nozzles to give a kind of peened finish. The operator should protect his nose and mouth with a wet sponge or respirator, and his hands with gloves.

With 25 to 30 pounds of air pressure a $\frac{1}{2}$-inch nozzle will use about 200 pounds of sand an hour.

Cubic Feet of Free Air per Minute Required for Nozzles of Varying Diameters

Diameter of Nozzle in Inches	Air Gage Pressures in Pounds								
	5	10	15	20	25	30	35	40	50
$\frac{1}{4}$	15.4	21.8	26.7	30.8	34.5	40	44.7	49	58.2
$\frac{5}{16}$	34.6	49	60	69	77	90	100	110.5	130
$\frac{3}{8}$	61.6	87	107	123	138	161	179	196	232
$\frac{7}{16}$	96.5	136	167	193	216	252	280	307	364
$\frac{1}{2}$	133	196	240	277	310	362	400	442	522
$\frac{9}{16}$	189	267	326	378	422	493	550	601	710

OILSTONES AND THEIR USES

Natural Stones

The following particulars regarding the well-known Arkansas and Washita stones are given by the Pike Manufacturing Company:

Arkansas stones are made from rock quarried in the Ozark mountains of Arkansas, and are prepared for commercial purposes in two grades, hard and soft.

Hard Arkansas is composed of pure silica and its sharpening qualities are due to small, sharp-pointed grains, or crystals, of hexagonal shape, which are much harder than steel and will, therefore, cut away and sharpen steel tools. The extreme fineness of texture makes this stone, of necessity, a slow cutter, but in the very density of the crystals of which it is composed lies its virtue as a sharpener

Soft Arkansas stone is not quite so fine-grained and hard as the hard Arkansas, but it cuts faster and is better for some kinds of mechanical work. It is especially adapted for sharpening the tools used by wood carvers, file makers, pattern makers, and all workers in hard wood.

Washita stone is also found in the Ozark mountains in Arkansas and is similar to the Arkansas stone, being composed of nearly pure silica, but is much more porous. It is known as the best natural stone for sharpening carpenters' and general woodworkers' tools. This stone is found in various grades, from perfectly crystallized and porous grit to vitreous flint and hard sandstone. The sharpness of the grit depends entirely upon its crystallization, the best oilstones being made from very porous crystals.

In addition to the regular rectangular sections, natural stones are made in such shapes as square, triangular, round, flat, bevel, diamond, oval, pointed, knife edge.

Artificial Oilstones

Artificial oilstones are manufactured in a multitude of shapes and sizes and are adapted for sharpening all kinds of tools. Such stones are made of alundum and crystolon, by the Norton Company, the former being known as India oilstones, the latter as crystolon sharpening stones. Similar shapes are manufactured by the Carborundum Company and others.

The stones are made in three grades or grits, coarse, medium and fine. The coarse stones are used in machine shops for sharpening very dull or nicked tools, machine knives and for general use where fast cutting is desired.

Medium stones are for sharpening mechanics' tools in general, more particularly those used by carpenters and in woodworking shops.

Fine stones are adapted for engravers, die workers, cabinet makers and other users of tools requiring a very fine, keen-cutting edge.

Of the great variety of shapes a number adapted especially for machine shop purposes are illustrated. Of these, stones like No. 24

are for sharpening lathe and planer tools, and for use after grinding; No. 23, is for reamers; No. 14 for taps; Nos. 4, 7, 10 and 26 for dies.

Two shapes for curved-edge woodworking tools are Nos. 10 and 14. A rectangular shape for straight-edge tools, like chisels, plane bits, planer knives, scrapers, paper-cutting knives and other tools with broad flat edges, is No. 24.

Some shapes suitable for die and tool work are shown by Nos. 4, 7, 26, 28 and 50. There are frequently several sizes in each shape.

How to Care for Oilstones

LIKE anything else, an oilstone can be ruined by wrong treatment and lack of care.

There are three objects to be attained in taking good care of an oilstone: first, to retain the original life and sharpness of its grit; second, to keep its surface flat and even; third, to prevent its glazing.

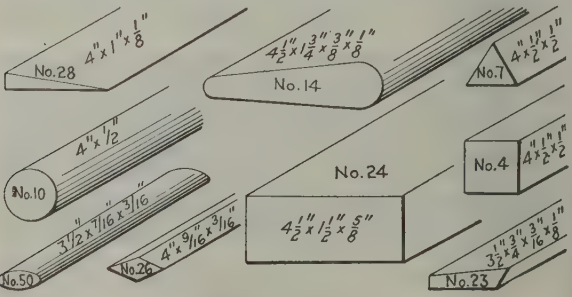


FIG. 24.—Oil Stone Shapes

To retain the original freshness of the stone, it should be kept clean and moist. To let an oilstone remain dry a long time or expose it to the air tends to harden it. A new natural stone should be soaked in oil for several days before it is used. If an oilstone is kept in a dry place (most of them are) it should be kept in a box having a closed cover, and a few drops of fresh, clean oil should be left on the stone.

To keep the surface of an oilstone flat and even simply requires care in using. Tools should be sharpened on the edge of a stone as well as in the middle, to prevent it from wearing down unevenly, and the stone should be turned end for end occasionally.

To restore an even, flat surface grind the oilstone on the side of a grindstone or rub it down with sandstone or an emery brick.

An oilstone can be prevented from glazing merely by use of oil or water.

Either oil or water is used on a sharpening stone to float the particles of steel that are cut away from the tool, thus preventing

them from filling in between the crystals and causing the stone to glaze.

Water—and plenty of it should be used on all coarse-grained natural stones.

On medium and fine-grained natural stones and in all artificial stones, oil should be used always, as water is not thick enough to keep the steel out of the pores.

Further to prevent glazing, the dirty oil should *always be wiped off the stone thoroughly* as soon as possible after using it. This is very important, for if left on the stone the oil dries in, carrying the steel dust with it. Cotton waste is one of the best things with which to clean a stone, and is nearly always to be found in a shop.

If the stone does become glazed or gummed up, a good cleaning with gasolene or ammonia will usually restore its cutting qualities, but if it does not, then scour the stone with loose emery or sandpaper fastened to a perfectly smooth board.

Never use turpentine on an oilstone for any purpose.

LAPPING, GRINDING AND HONING

The Reo pin is made of 1.000 $\pm \frac{005}{000}$ special-carbon, cold-drawn steel. It is carbonized 0.03 inch deep and hardened according to specifications so as to maintain a scleroscope hardness of 70 to 80. It is rough ground on a centerless grinder where five passes are taken, reducing the size to 0.985–0.9865 inch, with only 0.0005 inch removed in the last grind to prepare the pin for the series of finishing cuts.

Three finishing cuts are taken, removing 0.001, 0.0005 and 0.0002 inch at each cut. This last cut leaves the pin round and smooth enough so that the lapping machine can remove grinding marks.

The lapping machine carries 27 pins. The faces of the laps were narrowed down to enable the ends of the pins to leave the outer and inner edge; thus tending to keep the two laps parallel. The work fixture is mounted upon a peg set $1\frac{1}{4}$ inches off the true center of the revolving lower lap, the upper lap being stationary. The lower lap runs 72 r.p.m. and, by using No. 500 carborundum and light cylinder oil, which is brushed on the work, 0.0002 inch is removed at the rate of 160 pins per hour. The finish obtained is free from grinding marks, and has a good polish. The sizes of the finished pin are 0.9843 to 0.9844 inch, with a permissible taper of 0.0001 inch. To obtain this accuracy, it is necessary to relap the plates about every 300 pieces. This usually takes about 2 to 3 minutes, and is easily done.

Grinding.—Crank pins are sometimes ground from the rough. It can be done with a vitrified wheel of about 36–0, running at 6,600 feet per minute. The crank shaft runs at 90 r.p.m. and about $\frac{3}{8}$ inch of metal is removed.

Crank pins are finished with wheels of alundum 24 C-L vitrified, or their equivalent, at 6,200 feet per minute and a work speed of 45

r.p.m. About 10 pins can be ground per hour and the wheel will grind 10 before it is necessary to true it.

For grinding Norton master cams for automobile shafts an alundum elastic wheel of 46 grain and grade 3, or its equivalent, is used at 3,800 to 4,000 feet per minute. For rough grinding the wheel can be from $3\frac{1}{2}$ to $4\frac{1}{2}$ inches in diameter, but for finishing the master cam it must be between 3.998 and 4.002 inches.

Honing Cylinders.—Honing is used both in addition to grinding and to replace it. Where cylinders are ground first, the hones are usually alundum or carborundum blocks of about No. 180. They enlarge the bore about 0.001 inch in about 1 min. After that they cut very slowly.

Where cylinders are not ground, the first honing is usually done with No. 80 block and finished with No. 180, removing about 0.002 inch.

The hones travel through the bore, projecting an equal amount at each end, and rotate at the same time. Some run the hones 100 to 120 strokes a minute and revolve 10 to 15 times per minute. Others reverse this and run only 10 to 15 strokes and 100 to 120 r.p.m. This is claimed to be easier on the hone connections. Still others run about 125 strokes and revolve the hone at 100 r.p.m. An average honing time is about 2 minutes, including the handling of the block.

The hones are frequently spring mounted and follow the bore. Some mount them rigidly and remove more metal.

The hones are flooded with a mixture of kerosene and paraffine oil, in the ratio of 15:1. The paraffine is added solely because it is easier on the hands of the operator. A powerful magnet is placed at the end of the return pipe to the oil tank to catch the steel particles cut away by the hones.

Hones are sometimes glazed very quickly, but the glaze is readily removed by carefully rubbing a piece of abrasive wheel or block on the surface. Removing the glaze makes it possible to hone from 200 to 250 holes before truing the hones with the diamond.

When truing becomes necessary, the hone blocks are locked in position on the heads and soaked in kerosene for several hours. They are then put in a lathe and trued with a diamond. After soaking they cut readily and wear the diamond very little.

As evidence that there are high spots left by the grinding wheel that are removed by the hones, the effect on the size of the bore is cited by honing advocates. The hones will remove 0.001 inch from the bore of an average cylinder in about 1 minute. But the next minute or two they will remove very little.

The allowance for grinding is from 0.006 to 0.007 inch. If the cylinders are reamed, it is customary to allow from 0.012 to 0.015 inch for the reamer to bite into, rather than attempt to scrape out half this amount.

We are indebted to the Chandler and Reo Motor Car Co.'s for much of the data given.

SCREW MACHINE TOOLS, SPEEDS AND FEEDS

BOX TOOLS AND CUTTERS

The general principles of two types of box tools using respectively tangent and radial cutters are represented in Figs. 1 and 2. The former type is generally used for roughing and the latter for finishing. The tangent cutter in the type of box tool shown in Fig. 1 lies in a slot formed parallel to the bottom of the box but at an angle, usually ten degrees, with the front of the box, thus giving the

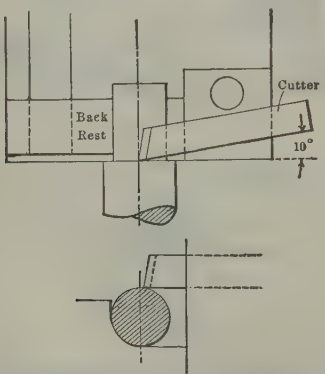


Fig. 1.—Roughing Box Tool with Tangent Cutter

desired rake at the cutting point. Finishing cutters of the type in Fig. 2 are straight on the end, located square with the work and ordinarily ground as indicated to give 7 to 10 degrees front clearance for steel and 5 to 8 degrees for brass.

The tangent cutter is sharpened by grinding on the end, and compensation for the grinding away of the metal is made by adjusting the cutter forward, whereas in the radial type of cutter in Fig. 2, frequent sharpening cannot be done without resulting in lowering the cutting edge of the tool below the center of the work, unless a substantial part of the tool be sacrificed. The radial tool, however, is easily ground accurately on face *a*, which is the edge governing the

finish; while the corresponding face on the tangent tool is rather difficult to grind so as to produce as smooth work.

The sizes of steel recommended for box-tool cutters are as follows: For box tools used for stock diameters up to $\frac{5}{16}$ inch, $\frac{3}{16}$ inch square; up to $\frac{3}{8}$ inch diameter, $\frac{7}{32}$ inch square; up to $\frac{1}{2}$ inch diameter, $\frac{1}{4}$ inch square; up to $\frac{3}{4}$ inch diameter, $\frac{5}{16}$ inch square; up to 1 inch diameter, $\frac{3}{8}$ inch square; up to $1\frac{1}{2}$ inches diameter, $\frac{1}{2}$ inch square.

HOLLOW MILLS

The teeth of hollow mills should be radial or ahead of the center. With the cutting edge ahead of the center, as in Fig. 3, the chips as produced are caused to move outward away from the work and pre-

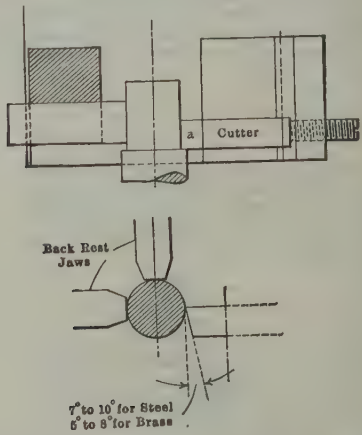
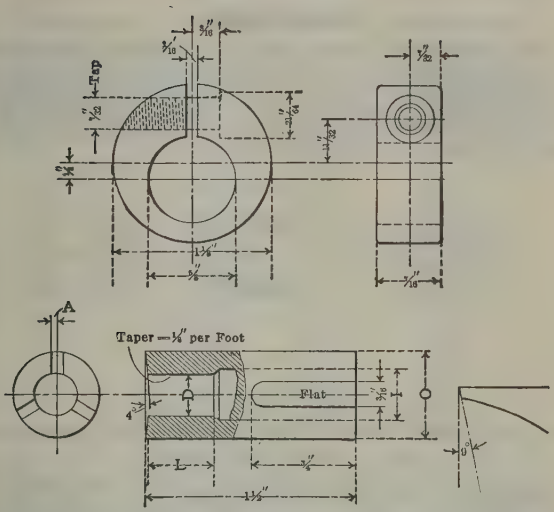


Fig. 2.—Finishing Box Tool with Radial Cutter

vented from disfiguring it. With the cutting edge below the center, rough turning will result. With the cutting edge greatly above the center, chattering occurs. About one tenth of the cutting diameter is a good average amount to cut the teeth ahead of the center. When the chips produced from any turning or boring cut curl nicely, it is indicative of a free cutting action; but these chips are very troublesome on the automatic screw machine. In making hollow mills for the automatic, part or all of the rake to the cutting edge is generally sacrificed.

The table under the hollow mill in Fig. 3 gives proportions of mills from $\frac{1}{16}$ to $\frac{3}{4}$ diameter, showing the amount to cut the teeth ahead of the center, the taper of the hole, etc.



D =	Finishing..	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	3/8	1/2	5/8	3/4
	Roughing .	.072	.104	.135	.166	.197	.229	.26	.291	.322	.385	.510	635	.760
	L =	1/4	1/4	5/16	5/16	3/8	3/8	7/16	7/16	1/2	5/8	3/4	7/8	1
	A = D/10 =	.006	.009	.012	.015	.019	.022	.025	.028	.031	.038	.050	.063	.075
	I =	3/16	3/16	3/16	3/16	5/16	3/8	3/8	3/8	3/8	7/16	9/16	11/16	13/16
	O =	3/8	3/8	3/8	5/8	5/8	5/8	5/8	5/8	5/8	1	1 1/4	1 3/8	1 5/8

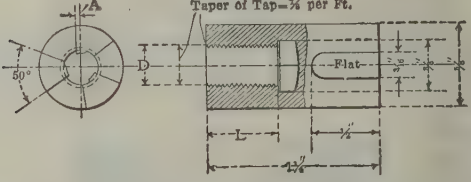
FIG. 3.—Hollow Mill Dimensions

DIES AND TAPS

IT is good practice in making spring screw dies either to hob out the thread with a hob tap 0.005 to 0.015 inch oversize, according to size, and in use to spring the prongs to proper cutting size by a clamping ring, or to tap the die out from the rear with a hob tap tapering from $\frac{3}{16}$ inch to $\frac{1}{4}$ inch per foot, leaving the front end about 0.002 inch over cutting size, and in this case also to use a clamping ring. Both of these schemes are for the purpose of obtaining back clearance and are effective. Of the two the use of the taper hob is to be preferred.

Spring Die Sizes

The table of dimensions for spring screw dies, Fig. 4, should prove of service, particularly for steel. For brass the cutting edge is radial, thus eliminating dimension *A*. The width of land at bottom of thread is usually made about one-fourth outside diameter of cut, the milling between flutes being 70 degrees, leaving 50 degrees for the prong in the case of three-flute dies.



SMALL SIZES OF DIES
(Overall Dimensions Given in Sketch)

D =	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	No. 3	4	6	8	10	12
Threads P. I. =	64	40	32	20	18	56	40	32	24–32	24–32	24–32
$A = \frac{D}{10}$	.006	.012	.019	.025	.031	.010	.011	.014	.016	.019	.021
L =	$\frac{5}{16}$	$\frac{3}{32}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{3}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$

SIZES $\frac{3}{8}$ TO 1 INCH

D =	$\frac{3}{8}$ to $\frac{1}{2}$	$\frac{1}{2}$ to $\frac{3}{4}$	$\frac{3}{4}$ to 1
Threads P. I. =	Std.	Std.	Std.
A =	$D \div 10$	$D \div 10$	$D \div 10$
L =	$\frac{3}{4}$	1"	$1\frac{1}{4}$
O.S. Dia.	1"	$1\frac{1}{4}$	$1\frac{3}{4}$
Length	2"	$2\frac{1}{4}$"	$2\frac{1}{2}$"

Fig. 4.—Spring Die Dimensions

Boring Work for Threading

In boring holes previously to tapping they should be somewhat larger than the theoretical diameter at bottom of thread, as the crowding action of the tap will cause the metal to flow some and compensate for this. Where no allowance is made, frequent tap breakage is liable to occur and torn threads in the work also. On external work it is for the same reasons advisable to turn the work undersize and the following table gives good average allowances for internal and external work.

ALLOWANCES FOR THREADING IN THE SCREW MACHINE

Threads per Inch	External Work Turn Undersize	Internal Work Increase Over Theoretical Bottom of Thread
28	0.002	0.004
24	0.002	0.0045
22	0.0025	0.005
20	0.0025	0.0055
16	0.003	0.006
14	0.003	0.0065
13	0.0035	0.007
12	0.0035	0.007
11	0.0035	0.0075
10	0.004	0.008
9	0.004	0.0085
8	0.0045	0.009
7	0.0045	0.0095
6	0.005	0.010

Tap Length and Number of Lands

The number of teeth in taps and the width of land should be regulated by the diameter and pitch of work as well as the nature of the material being cut. On fine threads, where a drunken thread is to be insured against, more teeth are required than on a coarser pitch of the same diameter. A good average number of teeth on taps for American standard threads is given in the following table.

Outside Dia.	No. of Flutes	Width of Land
$\frac{8}{16}$	4	$\frac{2}{64}$
$\frac{1}{4}$	4	$\frac{1}{16}$
$\frac{5}{16}$	4	$\frac{3}{64}$
$\frac{3}{8}$	4	$\frac{3}{32}$
$\frac{7}{16}$	4	$\frac{7}{64}$
$\frac{1}{2}$	4	$\frac{1}{8}$
$\frac{9}{16}$	4	$\frac{5}{32}$
$\frac{5}{8}$	4	$\frac{3}{16}$
$\frac{3}{4}$	4	$\frac{7}{32}$
$\frac{7}{8}$	4	$\frac{1}{4}$
1	4	$\frac{5}{16}$
$1\frac{1}{4}$	4	

With too few teeth and too short land very little support is afforded and this may cause chattering; too much land in contact causes heat due to excessive friction, welding of chips and torn threads.

FORMING TOOLS

THE two types of forming cutters commonly used in the screw machine are shown in Figs. 5 and 6. The circular forming cutter in Fig. 5 is usually cut away from $\frac{1}{8}$ to $\frac{3}{16}$ inch below center to give

suitable cutting clearance and the center of the tool post on which it is mounted is a corresponding amount above the center of the machine, so that the cutting edge of the circular tool is brought on the center line of the work. The relative clearance ordinarily obtained by circular cutters and dovetail tools of the type shown in Fig. 6, is indicated in Fig. 7. It is obvious that with a given material the larger the diameter of the work the greater the angle of

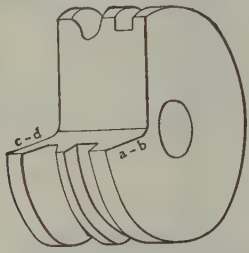


FIG. 5.—Circular Forming Tool

clearance required. Clearance angles are seldom less than 7 degrees or over 12 degrees.

The diameter of circular forming tools is an important matter for consideration. A small diameter has a more pronounced change of clearance angle than a large diameter. In fact, when of an exceedingly large diameter, the circular tool approaches in cutting action the dovetail type of tool which is usually provided with about 10

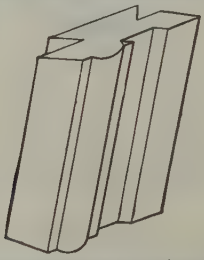


FIG. 6.—Dovetail Forming Tool

degrees clearance. Circular tools usually range from about $1\frac{3}{4}$ to 3 inches diameter, depending upon the size of machine in which they are used.

Getting the Tool Diameters at Different Points

In order to make a circular or a dovetail type of tool so that the contour of its cutting edge is such as to produce correct work, the

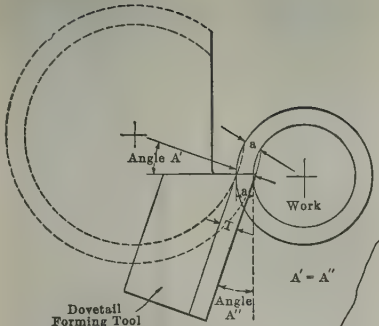


FIG. 7

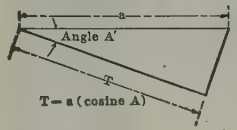


FIG. 9

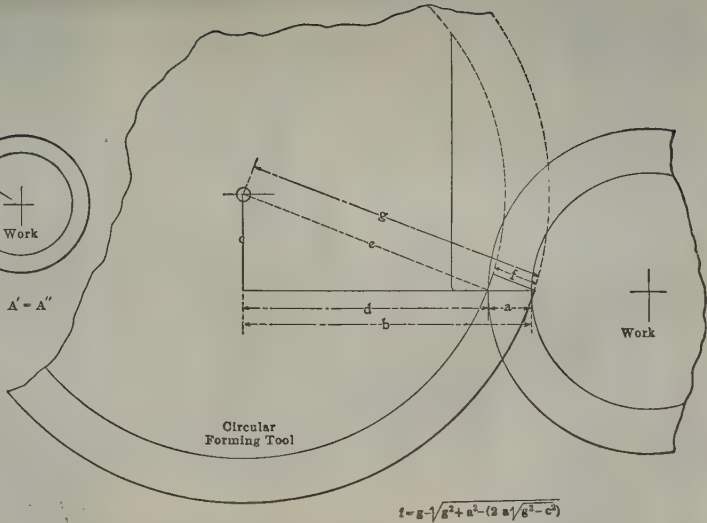


FIG. 8

Forming Tool Diameters and Depths

amount a circular tool is cut below center, as at c in Fig. 8, and the clearance angle of a dovetail tool as at A', Fig. 7 must be known. Thus, referring to Fig. 8, the forming tool shown cuts two different diameters on the work, the step between being represented by dimension a. To find depth f to which the forming tool must be finished on the center line to give the correct depth of cut a in the work (the cutter being milled below center an amount represented by c) the following formula may be applied:

$$f = g - \sqrt{g^2 + a^2 - (2a\sqrt{g^2 - c^2})}.$$

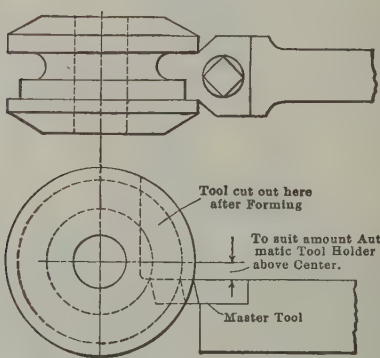


FIG. 10.—Finishing a Circular Tool

Suppose the depth of cut in the work represented by a to be 0.152"; the radius g of the forming cutter 1 inch; the distance c which the forming tool is milled below center, $\frac{3}{16}$ inch. Applying the above formula to find f and substituting the values just given for the letters in the formula we have $f = 1 - \sqrt{1 + .0231 - (.304\sqrt{1 - .03516})}$

$= 1 - \sqrt{1 + .0231 - (.304 \times .9823)}$

$= 1 - \sqrt{.724485} = 1 - .8512 = .1488$

Then $f = .1488$

Dovetail Tool Depths

If a similar piece of work is to be formed with a dovetail type of cutter, the distance T, Figs. 7 and 9, to which it is necessary to plane the tool shoulder in order that it may cut depth a correctly in the work, is found by the formula: $T = a$ (cosine A'). As 10 degrees is the customary clearance on this form of tool, the cosine of this angle, which is .98481, may be considered as a constant, making reference to a table of cosines unnecessary as a rule. As-

suming the same depth for a as in the previous case, that is .152 inch, and multiplying by .98481, gives .1496 inch as the depth of T to which the tool must be planed.

While it frequently is necessary or advisable to determine by calculation the dimension computed in the preceding examples, in the majority of cases when making a cutter with a master tool of the same outline as the model, the correct form in the circular cutter is obtained automatically by dropping the master tool to the same distance below the lathe center as the circular cutter is to be milled off center and then feeding it in to finish the cutter. This proce-

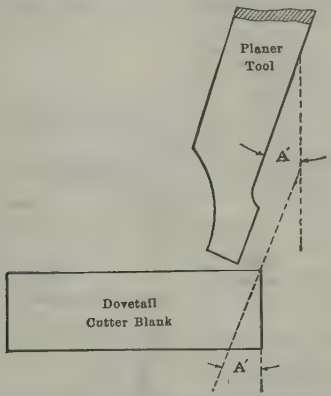


FIG. 11.—Finishing a Dovetail Forming Tool

dure, shown in Fig. 10, assures the correct shape at all points being produced on the exact working plane of the cutter. Similarly, in finishing a dovetail cutter in the planer or shaper, the master tool may be set as in Fig. 11 at the same angle with the cutter (usually 10 degrees) as the latter will afterward be applied to the work.

CIRCULAR TOOL FOR CONICAL POINTS

WHEN a circular cutter is to be made for forming a conical surface on a piece as in Fig. 12, a master tool of the exact angle required on the work may be used for finishing the cutter in the same way as the tool in Fig. 9 is applied; that is, the master is to be dropped below center the amount the cutter center is to be above the work center when in operation. The distance is represented by D in Fig. 12. Another method, which avoids the necessity of making a master tool, is to set the compound rest of the lathe to the exact angle required (in this case 30 degrees with the center line) and with a horizontal cutting tool set at distance D below center, turn off one

side of the cutter blank and then set the compound rest around the other way and face off the other side. If desired a similar method may be followed for grinding the forming cutter after hardening. The arbor carrying the cutter should be located either above or below the grinding wheel a distance equal to $D \frac{(R + r)}{r}$, where D equals the depth the cutter is milled below center, r the radius of the cutter, and R the radius of the grinding wheel. Assuming D to be .187 ($\frac{3}{16}$) inch; R, 2.5 inches; and r, 1 inch, the vertical distance between centers of forming tool and grinding wheel centers would equal $.187 \frac{(1 + 2.5)}{1} = .187\ (3.5) = .6562\ (\frac{21}{32})$ inch.

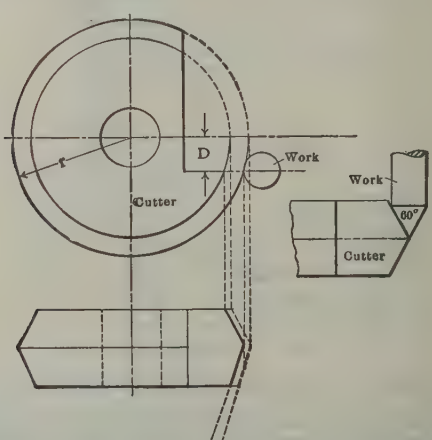


FIG. 12.—Circular Forming Tool for Conical Points

FINDING DIAMETERS OF CIRCULAR FORMING TOOLS

IN making circular forming tools it is oftentimes desirable to check the finished tool or finish a tool by grinding. It may also be advantageous to know the exact diameter a tool should be turned while making it, in order that calipering may be more convenient and certain. Methods of computing the diameter at different points are given on page 385, but in many cases of this kind the following tables will greatly facilitate matters, particularly when making circular forming tools for Brown & Sharpe automatic screw machines:

Suppose, for example, we have a piece to make like Fig. 13, on the No. 2 Brown & Sharpe automatic screw machine. The largest

diameter of the circular forming tool would produce the smallest diameter of the piece, which is 0.250 inch. The difference between this 0.250-inch diameter and the step of the 0.750-inch diameter is (0.750 − 0.250 inch) ÷ 2 = 0.250 inch.

The largest diameter of the circular forming tool for the No. 2 machine is 3 inches, which corresponds to a radius of 1.49998 inches with a base line of 1.479 inch for the triangle completed by the perpendicular joining the cutting line of the tool with the parallel line passing through the center of the tool.

The hypothenuse of the triangle is formed by the radius joining the intersection of the base line and the circumference of the tool as in Fig. 14. Subtracting 0.250 inch from 1.479 inches we have 1.229 inches, which, in Table 4, corresponds to a radius of 1.25417

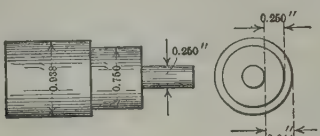


Fig. 13.—The Piece to Be Made

inches, and multiplying by 2 gives a diameter of 2.50834 inches, to which to turn the cutter to correctly form the 0.750-inch diameter on the piece, Fig. 13.

Considering the largest diameter of the piece and taking the height of the second step above the first diameter, we have $\frac{0.938 - 0.25}{2} =$ 0.344 inch, and subtracting from 1.479 = 1.135 for the base line, which, in Table 4, corresponds to a radius of 1.16221. Multiplying by 2 gives a diameter of 2.3244 to turn the cutter to in order to produce the 0.938-inch diameter on the work. Tables 2, 3 and 4 are for cutters of the dimensions given in Table 1.

These tables are figured in steps of 0.001 inch for the capacity of the machines. A difference of a fractional part of a thousandth can be added to the radius if the step is a part of a thousandth over the base-line figures, which are given in even thousandths. For illustration: Say the base-line figure is 1.4765 inches. In the table 1.476 inches corresponds to a radius of 1.49702; add 0.0005 inch to 1.49702 and the radius will be as near correct as it is practicable to make a cutter.

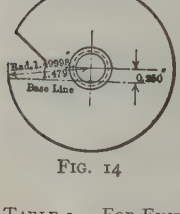


FIG. 14

TABLE 1.—DIMENSIONS OF CUTTERS FOR B. & S. AUTOMATIC SCREW MACHINES (Dimensions in Inches)

Mach. No.	Approx. Diam.	Max. Radius	Max. Base Line	Distance above or below Center
2 & 2G	3	1.49998	1.479	0.250
0 & 0G	2.250	1.12474	1.114	0.15625
00 & 00G	1.750	0.87497	0.866	0.125

TABLE 2.—FOR FINDING DIAMETERS OF CIRCULAR FORMING TOOLS FOR BROWN & SHARPE NO. 00 AUTOMATIC SCEW MACHINE

No. 00 & 00G		No. 00 & 00G		No. 00 & 00G		No. 00 & 00G		No. 00 & 00G	
Base Line	Radius	Base Line	Radius	Base Line	Radius	Base Line	Radius	Base Line	Radius
.866	.87497	.841	.85024	.815	.82453	.789	.79884	.763	.77317
.865	.87308	.840	.84925	.814	.82354	.788	.79785	.762	.77218
.864	.87300	.839	.84826	.813	.82255	.787	.79686	.761	.77120
.863	.87201	.838	.84727	.812	.82156	.786	.79588	.760	.77021
.862	.87102	.837	.84628	.811	.82058	.785	.79489	.759	.76922
.861	.87003	.836	.84529	.810	.81959	.784	.79390	.758	.76823
.860	.86904	.835	.84430	.809	.81860	.783	.79291	.757	.76725
.859	.86805	.834	.84332	.808	.81761	.782	.79193	.756	.76626
.858	.86706	.833	.84233	.807	.81662	.781	.79094	.755	.76528
.857	.86607	.832	.84134	.806	.81564	.780	.78995	.754	.76429
.856	.86508	.831	.84035	.805	.81465	.779	.78896	.753	.76330
.855	.86409	.830	.83936	.804	.81366	.778	.78798	.752	.76232
.854	.86310	.829	.83837	.803	.81267	.777	.78699	.751	.76133
.853	.86211	.828	.83738	.802	.81168	.776	.78600	.750	.76035
.852	.86112	.827	.83639	.801	.81069	.775	.78502	.749	.75936
.851	.86013	.826	.83540	.800	.80971	.774	.78403	.748	.75837
.850	.85914	.825	.83442	.799	.80872	.773	.78304	.747	.75739
.849	.85815	.824	.83343	.798	.80773	.772	.78205	.746	.75640
.848	.85716	.823	.83244	.797	.80674	.771	.78107	.745	.75541
.847	.85617	.822	.83145	.796	.80576	.770	.78008	.744	.75443
.846	.85518	.821	.83046	.795	.80477	.769	.77909	.743	.75344
.845	.85420	.820	.82947	.794	.80378	.768	.77811	.742	.75246
.844	.85321	.819	.82848	.793	.80279	.767	.77712	.741	.75147
.843	.85222	.818	.82750	.792	.80180	.766	.77613	.740	.75048
.842	.85123	.817	.82651	.791	.80082	.765	.77515		
		.816	.82552	.790	.79983	.764	.77416		

NOTE.—In the above Table 2 and Tables 3 and 4, it should be noted, as explained on page 389, that the Base Line dimensions in the columns under that heading and in the diagram, Fig. 14, are actually the distance of the cutting edge of the tool from the center of the cutter, the latter being used in the machine a certain distance either above or below the spindle center corresponding to Table 1. The distance from the cutting edge to center is therefore shorter than the true cutter radius by the amount indicated in the tables

TABLE 3.—FOR FINDING DIAMETERS OF CIRCULAR FORMING TOOLS FOR BROWN & SHARPE NO. 0 AUTOMATIC SCREW MACHINE

No. 0 & 0G		No. 0 & 0G		No. 0 & 0G		No. 0 & 0G		No. 0 & 0G	
Base Line	Radius	Base Line	Radius	Base Line	Radius	Base Line	Radius	Base Line	Radius
1.109	1.12474	1.060	1.07646	1.010	1.02726	.960	.97813	.910	.92911
1.108	1.12375	1.059	1.07547	1.009	1.02627	.959	.97715	.909	.92813
1.107	1.12277	1.058	1.07448	1.008	1.02529	.958	.97617	.908	.92715
1.106	1.12178	1.057	1.07350	1.007	1.02431	.957	.97519	.907	.92617
1.105	1.12079	1.056	1.07252	1.006	1.02332	.956	.97421	.906	.92519
1.104	1.11981	1.055	1.07153	1.005	1.02234	.955	.97323	.905	.92421
1.103	1.11882	1.054	1.07055	1.004	1.02136	.954	.97225	.904	.92324
1.102	1.11784	1.053	1.06956	1.003	1.02038	.953	.97127	.903	.92226
1.101	1.11685	1.052	1.06857	1.002	1.01939	.952	.97028	.902	.92128
1.100	1.11586	1.051	1.06759	1.001	1.01841	.951	.96930	.901	.92030
1.099	1.11488	1.050	1.06661	1.000	1.01743	.950	.96832	.900	.91932
1.098	1.11389	1.049	1.06563	.999	1.01644	.949	.96734	.899	.91834
1.097	1.11291	1.048	1.06464	.998	1.01546	.948	.96636	.898	.91732
1.096	1.11192	1.047	1.06366	.997	1.01448	.947	.96538	.897	.91638
1.095	1.11094	1.046	1.06267	.996	1.01349	.946	.96440	.896	.91540
1.094	1.10995	1.045	1.06169	.995	1.01251	.945	.96342	.895	.91442
1.093	1.10796	1.044	1.06070	.994	1.01153	.944	.96244	.894	.91345
1.092	1.10798	1.043	1.05972	.993	1.01055	.943	.96146	.893	.91247
1.091	1.10699	1.042	1.05874	.992	1.00957	.942	.96047	.892	.91149
1.090	1.10601	1.041	1.05775	.991	1.00858	.941	.95949	.891	.91051
1.089	1.10502	1.040	1.05677	.990	1.00760	.940	.95851	.890	.90953
1.088	1.10404	1.039	1.05578	.989	1.00662	.939	.95753	.889	.90855
1.087	1.10305	1.038	1.05480	.988	1.00563	.938	.95055	.888	.90757
1.086	1.10207	1.037	1.05381	.987	1.00465	.937	.95557	.887	.90660
1.085	1.10108	1.036	1.05283	.986	1.00367	.936	.95459	.886	.90562
1.084	1.10009	1.035	1.05185	.985	1.00269	.935	.95361	.885	.90464
1.083	1.09911	1.034	1.05086	.984	1.00170	.934	.95263	.884	.90366
1.082	1.09813	1.033	1.04988	.983	1.00072	.933	.95165	.883	.90268
1.081	1.09714	1.032	1.04889	.982	.99974	.932	.95067	.882	.90170
1.080	1.09616	1.031	1.04791	.981	.99875	.931	.94969	.881	.90073
1.079	1.09517	1.030	1.04693	.980	.99777	.930	.94871	.880	.89975
1.078	1.09418	1.029	1.04594	.979	.99679	.929	.94773	.879	.89877
1.077	1.09319	1.028	1.04496	.978	.99581	.928	.94675	.878	.89779
1.076	1.09221	1.027	1.04398	.977	.99483	.927	.94577	.877	.89681
1.075	1.09123	1.026	1.04299	.976	.99384	.926	.94479	.876	.89584
1.074	1.09024	1.025	1.04200	.975	.99286	.925	.94381	.875	.89486
1.073	1.08926	1.024	1.04102	.974	.99188	.924	.94283	.874	.89388
1.072	1.08828	1.023	1.04004	.973	.99090	.923	.94185	.873	.89290
1.071	1.08729	1.022	1.03906	.972	.98991	.922	.94087	.872	.89183
1.070	1.08630	1.021	1.03807	.971	.98893	.921	.93989	.871	.89095
1.069	1.08532	1.020	1.03709	.970	.98795	.920	.93891	.870	.88997
1.068	1.08433	1.019	1.03611	.969	.98697	.919	.93793	.869	.88899
1.067	1.08335	1.018	1.03512	.968	.98599	.918	.93695	.868	.88802
1.066	1.08236	1.017	1.03414	.967	.98501	.917	.93597	.867	.88704
1.065	1.08138	1.016	1.03316	.966	.98402	.916	.93499	.866	.88607
1.064	1.08039	1.015	1.03217	.965	.98304	.915	.93401	.865	.88508
1.063	1.07941	1.014	1.03119	.964	.98206	.914	.93303	.864	.88411
1.062	1.07842	1.013	1.03021	.963	.98108	.913	.93205	.863	.88313
1.061	1.07744	1.012	1.02922	.962	.98010	.912	.93107	.862	.88216
		1.011	1.02824	.961	.97912	.911	.93009	.861	.88118
								.860	.88020
								.859	.87922

TABLE 4.—FOR FINDING DIAMETERS OF CIRCULAR FORMING TOOLS FOR BROWN & SHARPE NO. 2 AUTOMATIC SCREW MACHINE

No. 2 & 2G		No. 2 & 2G		No. 2 & 2G		No. 2 & 2G		No. 2 & 2G	
Base Line	Radius	Base Line	Radius	Base Line	Radius	Base Line	Radius	Base Line	Radius
1.479	1.49998	1.430	1.45168	1.380	1.40246	1.330	1.35329	1.280	1.30419
1.478	1.49899	1.429	1.45070	1.379	1.40148	1.329	1.35231	1.279	1.30320
1.477	1.49801	1.428	1.44982	1.378	1.40050	1.328	1.35133	1.278	1.30222
1.476	1.49702	1.427	1.44873	1.377	1.39952	1.327	1.35035	1.277	1.30124
1.475	1.49604	1.426	1.44775	1.376	1.39853	1.326	1.34936	1.276	1.30026
1.474	1.49505	1.425	1.44676	1.375	1.39754	1.325	1.34838	1.275	1.29928
1.473	1.49406	1.424	1.44578	1.374	1.39656	1.324	1.34740	1.274	1.29830
1.472	1.49308	1.423	1.44479	1.373	1.39558	1.323	1.34641	1.273	1.29732
1.471	1.49209	1.422	1.44381	1.372	1.39459	1.322	1.34543	1.272	1.29633
1.470	1.49110	1.421	1.44282	1.371	1.39360	1.321	1.34445	1.271	1.29535
1.469	1.49012	1.420	1.44184	1.370	1.39262	1.320	1.34347	1.270	1.29437
1.468	1.48913	1.419	1.44085	1.369	1.39164	1.319	1.34248	1.269	1.29339
1.467	1.48815	1.418	1.43987	1.368	1.39066	1.318	1.34150	1.268	1.29241
1.466	1.48716	1.417	1.43874	1.367	1.38967	1.317	1.34052	1.267	1.29143
1.465	1.48618	1.416	1.43790	1.366	1.38869	1.316	1.33954	1.266	1.29045
1.464	1.48519	1.415	1.43090	1.365	1.38770	1.315	1.33855	1.265	1.28947
1.463	1.48421	1.414	1.43593	1.364	1.38672	1.314	1.33757	1.264	1.28848
1.462	1.48322	1.413	1.43495	1.363	1.38574	1.313	1.33659	1.263	1.28750
1.461	1.48223	1.412	1.43396	1.362	1.38475	1.312	1.33560	1.262	1.28652
1.460	1.48125	1.411	1.43298	1.361	1.38377	1.311	1.33462	1.261	1.28554
1.459	1.48026	1.410	1.43199	1.360	1.38279	1.310	1.33364	1.260	1.28456
1.458	1.47928	1.409	1.43100	1.359	1.38181	1.309	1.33266	1.259	1.28358
1.457	1.47829	1.408	1.43002	1.358	1.38082	1.308	1.33168	1.258	1.28260
1.456	1.47731	1.407	1.42905	1.357	1.37984	1.307	1.33069	1.257	1.28162
1.455	1.47632	1.406	1.42805	1.356	1.37885	1.306	1.32971	1.256	1.28064
1.454	1.47534	1.405	1.42707	1.355	1.37786	1.305	1.32873	1.255	1.27966
1.453	1.47435	1.404	1.42608	1.354	1.37689	1.304	1.32775	1.254	1.27868
1.452	1.47337	1.403	1.42510	1.353	1.37590	1.303	1.32677	1.253	1.27770
1.451	1.47238	1.402	1.42411	1.352	1.37492	1.302	1.32578	1.252	1.27672
1.450	1.47139	1.401	1.42313	1.351	1.37393	1.301	1.32480	1.251	1.27574
1.449	1.47041	1.400	1.42215	1.350	1.37295	1.300	1.32382	1.250	1.27476
1.448	1.46944	1.399	1.42116	1.349	1.37197	1.299	1.32284	1.249	1.27377
1.447	1.46846	1.398	1.42118	1.348	1.37098	1.298	1.32186	1.248	1.27279
1.446	1.46745	1.397	1.41919	1.347	1.37000	1.297	1.32087	1.247	1.27181
1.445	1.46647	1.396	1.41821	1.346	1.36902	1.296	1.31989	1.246	1.27083
1.444	1.46548	1.395	1.41723	1.345	1.36804	1.295	1.31891	1.245	1.26985
1.443	1.46459	1.394	1.41624	1.344	1.36705	1.294	1.31793	1.244	1.26887
1.442	1.46351	1.393	1.41526	1.343	1.36607	1.293	1.31695	1.243	1.26789
1.441	1.46253	1.392	1.41427	1.342	1.36509	1.292	1.31596	1.242	1.26691
1.440	1.46154	1.391	1.41329	1.341	1.36410	1.291	1.31498	1.241	1.26593
1.439	1.46056	1.390	1.41230	1.340	1.36312	1.290	1.31400	1.240	1.26495
1.438	1.45957	1.389	1.41132	1.339	1.36214	1.289	1.31301	1.239	1.26397
1.437	1.45853	1.388	1.41033	1.338	1.36116	1.288	1.31203	1.238	1.26299
1.436	1.45759	1.387	1.40935	1.337	1.36017	1.287	1.31106	1.237	1.26201
1.435	1.45661	1.386	1.40837	1.336	1.35919	1.286	1.31008	1.236	1.26103
1.434	1.45563	1.385	1.40738	1.335	1.35820	1.285	1.30909	1.235	1.26005
1.433	1.45464	1.384	1.40640	1.334	1.35722	1.284	1.30811	1.234	1.25907
1.432	1.45366	1.383	1.40541	1.333	1.35624	1.283	1.30713	1.233	1.25809
1.431	1.45267	1.382	1.40443	1.332	1.35526	1.282	1.30615	1.232	1.25711
		1.381	1.40345	1.331	1.35428	1.281	1.30517	1.231	1.25613

TABLE 4.—FOR FINDING DIAMETERS OF CIRCULAR FORMING TOOLS FOR BROWN & SHARPE NO. 2 AUTOMATIC SCREW MACHINE (*Continued*)

No. 2 & 2G		No. 2 & 2G		No. 2 & 2G		No. 2 & 2G		No. 2 & 2G	
Base Line	Radius	Base Line	Radius	Base Line	Radius	Base Line	Radius	Base Line	Radius
1.230	1.25515	1.178	1.20424	1.126	1.15342	1.074	1.10271	1.022	1.05213
1.229	1.25417	1.177	1.20326	1.125	1.15244	1.073	1.10174	1.021	1.05116
1.228	1.25319	1.176	1.20228	1.124	1.15147	1.072	1.10076	1.020	1.05019
1.227	1.25221	1.175	1.20130	1.123	1.15049	1.071	1.09979	1.019	1.04920
1.226	1.25123	1.174	1.20032	1.122	1.14951	1.070	1.09882	1.018	1.04825
1.225	1.25025	1.173	1.19934	1.121	1.14854	1.069	1.09784	1.017	1.04728
1.224	1.24927	1.172	1.19837	1.120	1.14756	1.068	1.09687	1.016	1.04631
1.223	1.24829	1.171	1.19739	1.119	1.14659	1.067	1.09590	1.015	1.04533
1.222	1.24731	1.170	1.19641	1.118	1.14561	1.066	1.09492	1.014	1.04436
1.221	1.24633	1.169	1.19543	1.117	1.14463	1.065	1.09395	1.013	1.04339
1.220	1.24535	1.168	1.19446	1.116	1.14366	1.064	1.09298	1.012	1.04242
1.219	1.24437	1.167	1.19348	1.115	1.14268	1.063	1.09200	1.011	1.04145
1.218	1.24339	1.166	1.19250	1.114	1.14171	1.062	1.09103	1.010	1.04048
1.217	1.24241	1.165	1.19152	1.113	1.14073	1.061	1.09006	1.009	1.03951
1.216	1.24143	1.164	1.19054	1.112	1.13976	1.060	1.08908	1.008	1.03854
1.215	1.24045	1.163	1.18957	1.111	1.13878	1.059	1.08811	1.007	1.03757
1.214	1.23947	1.162	1.18859	1.110	1.13780	1.058	1.08714	1.006	1.03660
1.213	1.23849	1.161	1.18761	1.109	1.13683	1.057	1.08616	1.005	1.03563
1.212	1.23752	1.160	1.18663	1.108	1.13586	1.056	1.08519	1.004	1.03466
1.211	1.23654	1.159	1.18566	1.107	1.13488	1.055	1.08422	1.003	1.03369
1.210	1.23556	1.158	1.18468	1.106	1.13390	1.054	1.08324	1.002	1.03273
1.209	1.23458	1.157	1.18370	1.105	1.13293	1.053	1.08227	1.001	1.03175
1.208	1.23360	1.156	1.18272	1.104	1.13195	1.052	1.08130	1.000	1.03078
1.207	1.23262	1.155	1.18175	1.103	1.13098	1.051	1.08032	.999	1.02981
1.206	1.23164	1.154	1.18077	1.102	1.13000	1.050	1.07935	.998	1.02884
1.205	1.23066	1.153	1.17979	1.101	1.12903	1.049	1.07838	.997	1.02787
1.204	1.22968	1.152	1.17881	1.100	1.12805	1.048	1.07741	.996	1.02690
1.203	1.22870	1.151	1.17784	1.099	1.12708	1.047	1.07643	.995	1.02593
1.202	1.22772	1.150	1.17686	1.098	1.12610	1.046	1.07546	.994	1.02496
1.201	1.22675	1.149	1.17588	1.097	1.12513	1.045	1.07449	.993	1.02399
1.200	1.22577	1.148	1.17491	1.096	1.12415	1.044	1.07352	.992	1.02302
1.199	1.22479	1.147	1.17393	1.095	1.12318	1.043	1.07254	.991	1.02205
1.198	1.22381	1.146	1.17295	1.094	1.12220	1.042	1.07157	.990	1.02108
1.197	1.22283	1.145	1.17197	1.093	1.12123	1.041	1.07060	.989	1.02011
1.196	1.22185	1.144	1.17100	1.092	1.12025	1.040	1.06963	.988	1.01914
1.195	1.22087	1.143	1.17002	1.091	1.11928	1.039	1.06865	.987	1.01817
1.194	1.21989	1.142	1.16904	1.090	1.11830	1.038	1.06768	.986	1.01720
1.193	1.21891	1.141	1.16807	1.089	1.11733	1.037	1.06671	.985	1.01623
1.192	1.21793	1.140	1.16709	1.088	1.11635	1.036	1.06574	.984	1.01526
1.191	1.21696	1.139	1.16612	1.087	1.11538	1.035	1.06477	.983	1.01429
1.190	1.21598	1.138	1.16514	1.086	1.11440	1.034	1.06379	.982	1.01332
1.189	1.21500	1.137	1.16416	1.085	1.11343	1.033	1.06282	.981	1.01235
1.188	1.21402	1.136	1.16318	1.084	1.11246	1.032	1.06185	.980	1.01139
1.187	1.21304	1.135	1.16221	1.083	1.11148	1.031	1.06088	.979	1.01042
1.186	1.21206	1.134	1.16123	1.082	1.11051	1.030	1.05991	.978	1.00945
1.185	1.21108	1.133	1.16025	1.081	1.10953	1.029	1.05893	.977	1.00848
1.184	1.21011	1.132	1.15928	1.080	1.10856	1.028	1.05796	.976	1.00751
1.183	1.20913	1.131	1.15830	1.079	1.10758	1.027	1.05699	.975	1.00654
1.182	1.20815	1.130	1.15732	1.078	1.10661	1.026	1.05602	.974	1.00557
1.181	1.20717	1.129	1.15635	1.077	1.10563	1.025	1.05505	.973	1.00460
1.180	1.20619	1.128	1.15537	1.076	1.10466	1.024	1.05408	.972	1.00363
1.179	1.20521	1.127	1.15440	1.075	1.10369	1.023	1.05310	.971	1.00267
								.970	1.00170

SPEEDS AND FEEDS FOR SCREW MACHINE WORK

The accompanying tables are from the practice advocated by the Brown & Sharpe Mfg. Co. They recommend the following speeds for the drive shafts of their automatic screw machines, for all spindle speeds.

No. 00	No. 0	No. 2
120 r.p.m.	180 r.p.m.	120 r.p.m.

The tables are very complete and cover a large variety of work in very compact form.

Bolt Cutters

For threading cast iron in machines of the bolt cutter type, the Landis Machine Company, Waynesboro, Pa., gives these speeds:

Inches	1/4	3/8	1/2	3/4	1	1 1/2	2
R.p.m.	380	255	190	125	95	65	50

with petroleum as a lubricant.

For soft steel and iron:

Inches	1/4	3/8	1/2	3/4	1	1 1/2	2
R.p.m.	520	355	265	175	135	75	55

with compound or screw-cutting oil as a lubricant.

These figures are based on a circumferential cutting speed of 25 feet per minute for cast iron and 35 feet per minute for soft steel and iron up to and including 1 inch, and 30 feet per minute for 1½-inch and 2-inch sizes. The speeds are for high-speed steel chasers. Some users run the machines at a higher rate.

Approximate Cutting Speeds and Feeds for Standard Tools

Please bear in mind these figures are only approximate, to be used as a basis from which proper figures for the job in hand may be calculated. They are averages, and if the work has any features out of the ordinary take these into consideration and alter the figures accordingly.

Feed—is feed per revolution. Speed—is maximum surface speed of stock in feet per minute.

The same feed is used for both carbon and high-speed steel cutting tools, the cutting speed only being different.

Tool	Cut		Material						
			Brass Free Cutting		Mild or Soft Steel 0.10–0.20 % Carbon			Tool Steel 0.80–1.00 % Carbon		
	Width or Depth	Diam. of Hole	Feed	Speed in Surface Feet	Feed	Speed in Surface Feet		Feed	Speed in Surface Feet	
						Carbon Tools	H.S.S. Tools		Carbon Tools	H.S.S. Tools
Boring tools	0.005				0.004	50	75	0.003	30	45
Box tools:										
Roughing	$\frac{1}{32}$		0.009		0.006	70	105	0.005	40	60
	$\frac{1}{16}$		0.008		0.005	70	105	0.004	40	60
	$\frac{1}{8}$		0.005		0.004	70	105	0.003	40	60
	$\frac{3}{16}$		0.004		0.003	70	105	0.002	40	60
	$\frac{1}{4}$		0.0035		0.002	70	105	0.0015	40	60
Finishing	0.005		0.010		0.010	70	120	0.006	40	60
Center drills		Under $\frac{1}{8}$	0.002		0.0015	50	75	0.001	30	45
		Over $\frac{1}{8}$	0.005		0.0025	50	75	0.002	30	45
Cut-off tools:										
Angular			0.0012		0.0006	80	120	0.0004	50	75
Circular	$\frac{3}{4}-\frac{1}{8}$		0.002		0.0015	80	120	0.001	50	75
Straight	$\frac{1}{16}-\frac{1}{8}$		0.002		0.0015	80	120	0.001	50	75
Diameter stock under $\frac{1}{8}$ inch			0.001		0.0008	80	120	0.0005	50	75
Dies						30			14	

Approximate Cutting Speeds and Feeds for Standard Tools

Please bear in mind these figures are only approximate, to be used as a basis from which proper figures for the job in hand may be calculated. They are averages, and if the work has any features out of the ordinary take these into consideration and alter the figures accordingly.

Feed—is feed per revolution. Speed—is maximum surface speed of stock in feet per minute.

The same feed is used for both carbon and high-speed steel cutting tools, the cutting speed only being different.

Tool	Cut		Brass Free Cutting		Material				
					Mild or Soft Steel 0.10–0.20% Carbon			Tool Steel 0.80–1.00% Carbon		
	Width or Depth	Diam. of Hole	Feed	Speed in Surface Feet	Feed	Speed in Surface Feet		Feed	Speed in Surface Feet	
						Carbon Tools	H.S.S. Tools		Carbon Tools	H.S.S. Tools
Drills:										
Twist cut		0.02	0.0014		0.001	40	60	0.0006	30	45
		0.04	0.002		0.0014	40	60	0.0008	30	45
		1/16	0.003		0.002	40	60	0.0012	30	45
		3/32	0.004		0.0025	40	60	0.0016	30	45
		1/8	0.006		0.003	40	60	0.002	30	45
		5/16	0.008		0.0035	40	60	0.0024	30	45
		1/4	0.0095		0.004	40	60	0.0028	30	45
		5/16	0.011		0.0045	40	60	0.0032	30	45
		3/8	0.012		0.005	40	60	0.0035	30	45
		1/2	0.012		0.005	40	60	0.0035	30	45
		5/8	0.012		0.005	40	60	0.0035	30	45
Form tools—circular	1/8–1/4		0.0015		0.0006	80	120	0.0004	50	75
	3/8–1/2		0.001		0.0005			0.0003		
			0.001		0.0005	80	120	0.0002	50	75
	5/8–3/4		0.0008		0.0004					
	1		0.0008		0.0004	80	120	0.0002	50	75
			0.0007		0.0003	80	120			
Hollow mills and balance turning tools										
Turned diameter under 5/32 inch	1/32		0.0085		0.006	70	120	0.005	40	60
	1/16		0.0075		0.005	70	120	0.004	40	60

Turned diameter over $\frac{5}{32}$ inch	$\frac{1}{32}$		0.017	Use maximum spindle speed available on machine.	0.012	70	120	0.010	40	60
	$\frac{1}{16}$		0.015		0.010	70	120	0.008	40	60
	$\frac{1}{8}$		0.010		0.008	70	120	0.006	40	60
	$\frac{3}{16}$		0.008		0.006	70	120	0.0045	40	60
	$\frac{1}{4}$		0.007		0.0045	70	120	0.003	40	60
Knee tools	$\frac{1}{64}$ - $\frac{1}{32}$				0.010	70	105	0.010	40	60
					0.012			0.008		
Knurl tools										
Turret	On		0.020							
	Off		0.040		0.015	100	150	0.010	70	105
Side or swing			0.004		0.030	100	150	0.025	70	105
			0.006		0.002	100	150	0.002	70	105
Top			0.005		0.004	100	150	0.003	70	105
			0.008		0.003	100	150	0.002	70	105
Pointing and facing tools			0.001		0.006	100	150	0.004	70	105
			0.0018		0.0008	70	105	0.0005	40	60
Reamers and bits	0.003 to 0.004	$\frac{1}{8}$ or less	0.010– 0.007		0.0015 – 0.008–	70	105	0.0008 – 0.006	40	60
	0.004 to 0.008	$\frac{1}{8}$ or over	0.010		0.006	70	105	0.004	40	60
					0.010	70	105	0.006	40	60
								0.008	40	60
Recessing tools:										
End cut			0.001		0.0006	70	105	0.0004	40	60
			0.003		0.002	70	105	0.001	40	60
Inside cut	$\frac{1}{16}$–$\frac{1}{8}$		0.001		0.001	70	105	0.0008	40	60
			0.0008		0.0006	70	105	0.0004	40	60
Swing tools:										
Forming	$\frac{1}{8}$–$\frac{1}{4}$		0.001		0.0004	70	105	0.0003	40	60
			0.0007		0.0003	70	105	0.0002	40	60
	$\frac{3}{8}$–$\frac{1}{2}$		0.0007		0.0003	70	105	0.0002	40	60
			0.0006							
Turning straight	$\frac{1}{32}$		0.004		0.003	70	105	0.0025	40	60
	$\frac{1}{16}$		0.0035		0.0025	70	105	0.002	40	60
	$\frac{1}{8}$		0.0025		0.002	70	105	0.0015	40	60
	$\frac{3}{16}$		0.002		0.0015	70	105	0.001	40	60
Taps						25			12	
Swing tools										

Taper tuning same as straight turning, but the feed is taken slow enough for the greatest depth of cut.

Threading Speeds for Taps and Dies
drop forgings

Diam.	Surface Feet	R.p.m.
$\frac{1}{8}$	25	765
$\frac{3}{16}$	25	509
$\frac{1}{4}$	25	382
$\frac{5}{16}$	23	305
$\frac{3}{8}$	23	235
$\frac{7}{16}$	23	201
$\frac{1}{2}$	23	176
$\frac{9}{16}$	23	156
$\frac{5}{8}$	23	141
$\frac{11}{16}$	23	128
$\frac{3}{4}$	23	117
$\frac{13}{16}$	23	108
$\frac{7}{8}$	23	100
$\frac{15}{16}$	23	94
1	20	77
$1\frac{1}{4}$	20	61
$1\frac{1}{2}$	20	51
2	18	35

Brown & Sharpe Automatic Acorn Dies
screw stock

$\frac{1}{8}$	28	855
$\frac{1}{4}$	28	428
$\frac{5}{16}$	28	342
$\frac{3}{8}$	28	285
$\frac{7}{16}$	28	244
$\frac{1}{2}$	28	214
$\frac{9}{16}$	28	190
$\frac{5}{8}$	28	171
$\frac{11}{16}$	28	156
$\frac{3}{4}$	28	143
$\frac{13}{16}$	28	132
$\frac{7}{8}$	28	122
$\frac{15}{16}$	28	114
1	28	107

TABLE 1.—THREADING SPEEDS FOR HIGH-SPEED STEEL CHASERS
(For Carbon Steel Chasers Use 60 Per Cent of this Speed)
(Geometric Tool Co.)

Material	Surface Speeds for Threads Per Inch		
	3½–7½	8–11	12–32
Tool steel	5	8	10
Vanadium steel—monel metal—nickel steel—forged steel—open hearth	10	15	20
Bessemer screw stock—tobin bronze—drawns teel—machine steel	20	30	50
Cast iron—malleable iron	25	50	80
Copper—phosphor bronze	40	80	150
Cast brass—bar brass—rubber fiber—aluminum—lead	50	100	200

TABLE 2

Surface speed	5	8	10	15	20	25	30	40	50	80	100	150	200
Diam. of Work, Inches	R.p.m.												
1/8	152	245	305	458	611	764	917	1222	1528	2445	3056	4584	6112
1/4	76.5	122	153	229	306	382	458	611	764	1222	1528	2292	3056
3/8	51.0	81.4	102	153	204	255	306	407	509	815	1019	1528	2038
1/2	38.2	61.2	76.5	115	153	191	229	306	382	611	764	1146	1528
5/8	30.5	48.8	61.0	91.7	122	153	183	244	306	489	611	917	1222
3/4	25.5	40.8	51.0	76.4	102	127	153	204	255	407	509	764	1018
7/8	21.8	35.0	43.6	65.5	87.3	109	131	175	218	349	437	655	874
1	19.1	30.6	38.2	57.3	76.4	95.5	115	153	191	306	382	573	764
1 1/8	16.9	27.2	33.9	50.9	67.9	84.9	102	136	170	272	340	509	680
1 1/4	15.2	24.4	30.5	45.8	61.1	76.4	91.7	122	153	244	306	458	612
1 3/8	13.9	22.2	27.8	41.7	55.6	69.5	83.3	111	139	222	278	417	556
1 1/2	12.7	20.4	25.4	38.2	50.9	63.7	76.4	102	127	204	255	382	510
1 5/8	11.7	18.8	23.5	35.3	47.0	58.8	70.5	94.0	118	188	235	353	470
1 3/4	10.9	17.4	21.8	32.7	43.7	54.6	65.5	87.3	109	175	218	327	436
1 7/8	10.1	16.3	20.3	30.6	40.7	50.9	61.1	81.5	102	163	204	306	408
2	9.5	15.3	19.1	28.7	38.2	47.7	57.3	76.4	95.5	153	191	287	382
2 1/4	9.0	14.4	18.0	27.0	36.0	45.0	54.0	72.0	90.0	144	180	270	360
2 1/2	8.5	13.6	17.0	25.5	34.0	42.4	50.9	67.9	84.9	136	170	255	340
2 3/4	8.0	12.9	16.1	24.1	32.2	40.3	48.3	64.4	80.5	129	161	242	322
2 3/4	7.6	12.2	15.3	22.9	30.6	38.2	45.8	61.1	76.4	122	153	229	306
2 3/4	7.2	11.6	14.5	21.7	29.0	36.3	43.5	58.0	72.5	116	145	218	290
2 3/4	6.9	11.1	13.9	20.8	27.8	34.7	41.7	55.6	69.5	111	139	208	278
2 3/4	6.6	10.5	13.2	19.8	26.4	33.0	39.6	52.8	66.0	106	132	198	264
3	6.3	10.1	12.7	19.1	25.5	31.8	38.2	50.9	63.7	102	127	191	254
3 1/4	6.1	9.7	12.2	18.3	24.4	30.5	36.6	48.8	61.0	97.6	122	183	244
3 1/4	5.8	9.4	11.7	17.6	23.5	29.4	35.3	47.0	58.8	94.0	118	176	236
3 1/4	5.6	9.0	11.3	16.9	22.6	28.3	33.9	45.2	56.5	90.4	113	170	226
3 1/4	5.4	8.5	10.9	16.4	21.8	27.3	32.7	43.7	54.6	87.3	109	164	218
3 1/4	5.2	8.4	10.5	15.7	21.0	26.3	31.5	42.0	52.5	84.0	105	158	210
3 1/4	5.1	8.1	10.2	15.3	20.4	25.5	30.6	40.7	50.9	81.5	102	153	204
3 1/4	4.9	7.9	9.8	14.8	19.7	24.6	29.6	39.4	49.3	78.8	98.5	148	197
4	4.7	7.6	9.5	14.3	19.1	23.9	28.7	38.2	47.7	76.4	95.5	143	191

Speeds and Feeds

The following threading speeds can be used with either tap or die as a working basis. These speeds will have to be varied to suit the job.

Cast and Malleable Iron and Screw Stock

Diam. in Inches	Surface Feet	R.P.M.
$\frac{1}{8}$	40	1,222
$\frac{3}{16}$	40	814
$\frac{1}{4}$	40	611
$\frac{5}{16}$	40	490
$\frac{3}{8}$	35	356
$\frac{7}{16}$	35	305
$\frac{1}{2}$	35	267
$\frac{9}{16}$	35	240
$\frac{5}{8}$	35	210
$\frac{11}{16}$	35	195
$\frac{3}{4}$	35	178
$\frac{13}{16}$	35	165
$\frac{7}{8}$	35	153
$\frac{15}{16}$	30	122
1	30	115
$1\frac{1}{4}$	30	92
$1\frac{1}{2}$	30	76
2	25	48

Threading Speeds—Brass

$\frac{1}{8}$	135	4,126
$\frac{3}{16}$	135	2,750
$\frac{1}{4}$	125	1,909
$\frac{5}{16}$	125	1,528
$\frac{3}{8}$	120	1,222
$\frac{1}{2}$	120	917
$\frac{5}{8}$	120	715
$\frac{3}{4}$	115	586
1	110	420
$1\frac{1}{4}$	100	306
$1\frac{1}{2}$	90	229
2	85	162

Aluminum

120 surface feet per minute

In some cases they can be increased if the metal is free cutting; in other cases they will have to be reduced because of the opposite condition, but they serve as a very good basis.

In tests, $\frac{3}{8}$ inch drills have been run up to 99 feet per minute, in cast iron, with feeds up to 0.104 inch per revolution, removing nearly 12 pounds of metal per minute; $1\frac{1}{4}$-inch drills were run 260 feet per minute with a feed of 0.145 inch per revolution, removing 37 pounds of metal per minute. This is drilling at the rate of 116 inches per minute. In machinery steel, the speed of a $1\frac{1}{2}$-inch drill was 180 feet per minute, the feed 0.0815 inch per revolution, removing 15.5 pounds of metal and drilling at the rate of 44.8 inches per minute.

SPEED OF REAMERS IN SCREW MACHINE WORK

The Cleveland Twist Drill Company find the following to be satisfactory in their screw machine department:

CARBON REAMERS

	Cast Iron	Machinery Steel	Tool Steel	Brass
Cutting speed.....	30 ft.	30 ft.	15–20 ft.	100 ft.
Feed per revolution:				
$\frac{1}{4}$-inch hole.....	0.009 in.	0.004 in.	0.004 in.	0.007 in.
$1\frac{1}{8}$-inch hole.....	0.023	0.015	0.011	0.015
2-inch hole.....	0.033	0.020	0.016	0.020

HIGH-SPEED REAMERS

	Cast Iron and Machinery Steel	Tool Steel	Brass
Cutting speed.....	50–60 ft.	25–30 ft.	130–150 ft.

Feeds the same as given above for carbon tools.

The amount of stock left in hole for reaming is from about 0.004 inch for $\frac{1}{4}$-inch size to about 0.009 inch for 2-inch size. For intermediate sizes, the speeds and feeds will be approximately proportional to those given.

For commercial automobile steels, in some cases the speed may be as high as stated for machinery steel. For the best grades of finish, they recommend carbon reamers at very slow speeds, but good commercial finish within acceptable tolerances can be obtained on a production basis using the feeds, speeds and amount of stock

given above. Soda water is satisfactory as a lubricant except on automatic machines, where a mineral lard oil is used.

It is also important to use the floating tool holder, and they feel that sufficient emphasis is not usually placed on this attachment.

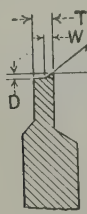
Table of Angles and Thicknesses for Circular Cutting-off Tools

W is same as *T* up to 0.060 inch inclusive.

W is same as one-half *T* from 0.070 to 0.120 inch thickness inclusive.

W is 0.060 for 0.140 inch thickness and over.

A is 23 degrees when cutting brass, aluminum, copper, silver and zinc.



A is 15 degrees when cutting steel, iron, bronze and nickel.

Least thickness used when cutting off into tapped holes is the lead of two and one-half threads plus 0.010 inch.

Least thickness used when cutting off into reamed holes smaller than $\frac{1}{8}$-inch diameter is 0.040 inch.

Thickness used when cutting off tubing is two-thirds *T* as given below for corresponding diameters.

Thickness used when angles or radii start from outside diameter of tool is governed by varying conditions and determined accordingly.

	Diameter of Stock																			
	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$–$\frac{15}{16}$	$\frac{3}{4}$–$\frac{7}{8}$	$\frac{13}{16}$–1	1 $\frac{1}{16}$–1 $\frac{1}{8}$	1 $\frac{3}{16}$–1 $\frac{7}{8}$	2–2 $\frac{1}{4}$
Thickness *T*	.020	.030	.040	.050	.060	.070	.080	.090	.100	.120	.140	.160	.190	.220
Depth of angle *D* For brass	.0085	.013	.017	.0215	.0255	.015	.017	.019	.0215	.0255	.035	.0255	.0255	.0255
Depth of angle *D* For steel	.0055	.008	.011	.0135	.016	.0095	.011	.012	.0135	.016	.010	.010	.010	.010

Tolerances for Pieces Made in Screw Machines (Outside Diameters)

Running Fits not to be Ground

To $\frac{1}{2}$-inch diam. inclusive..... 0.0005–0.0015 inch small
To 1-inch diam. inclusive..... 0.001 –0.002 inch small
To 2-inch diam. inclusive..... 0.0015–0.0025 inch small
To $3\frac{1}{2}$-inch diam. inclusive..... 0.0015–0.003 inch small

Standard Fits not to be Ground—All Sizes

Standard to 0.001 inch small

Driving Fits not to be Ground—All Sizes

0.0005 to 0.0015 inch large

Pieces to be Ground—Amount of Stock to be Left for Grinding

To 1-inch diam. inclusive..... 0.005–0.007 inch large
To 2-inch diam. inclusive..... 0.007–0.010 inch large
To $3\frac{1}{2}$-inch diam. inclusive..... 0.010–0.014 inch large

Screw Machine Limit.—Work made on screw machines cannot be made practically to a closer limit than 0.0005 inch either side of a fixed figure (0.001-inch limit). If closer work is required, it must be made large and ground to limit required. If no limit is given on the large part of piece and if not otherwise stated, it can be left stock size.

Grinding Allowance for Bronze Bushings (Outside Diameters)

Grind $\left\{\begin{matrix} 0.001 \text{ inch} \\ 0.0015 \text{ inch} \end{matrix}\right\}$ Large

Standard Holes (Reamed).—All holes, including parts made in screw machines, unless otherwise specified, are standard diameters. Plugs 0.0005 inch small should go in. Standard plug should wring in. Plugs 0.0005 inch large should not go in.

Operating screws should be ground on the outside diameter of the threaded portion to a limit of Standard to 0.002 inch small.

PUNCH PRESS TOOLS

METHOD OF FINDING THE DIAMETERS OF SHELL BLANKS

This method for the finding of diameters of shell blanks applies also to other shapes which frequently occur in practice.

The method is based upon the surface of the shell in comparison with the area of the blank and should, therefore, be used only when light material is to be considered. In case of the flanged shapes the width of the flange should be small in proportion to the diameter.

Cylindrical Shell

Fig. 1 shows a cylindrical shell of the diameter d and the depth h. To find the diameter of the blank, lay down the diameter d of the shell twice on a horizontal line, Fig. 2, add to this a distance equal to four times the depth h of the shell and describe a semicircle of which the total distance is the diameter. The vertical line D from the intersecting point with the circle to the horizontal line gives the desired blank diameter. Line D is to be drawn at a distance d from the end of the horizontal.

Flanged Shells

If the shell has a flange as in Fig. 3, use the formula shown in Fig. 4.

In the case of a hemisphere, Fig. 5, lay down the diameter three times on the horizontal line and draw the vertical line at the distance d from the end, as in Fig. 6. The width of flange $= a$.

If the hemisphere has a flange as in Fig. 7, add a distance equal to twice the width of the flange to the horizontal line, as in Fig. 8. In any case, the length of the vertical line D gives the desired diameter of blank.

Taper Shells

If a shell with tapering sides, Fig. 9, has to be drawn, multiply first the bottom diameter by itself and divide the product by the sum of the two diameters d_1 and d in order to obtain the length x. Otherwise proceed as shown in Fig. 10.

Flanged Taper Shells

If the taper shell has a flange of the width a, Fig. 11, add to the base line of the diagram twice this width, as shown in Fig. 12.

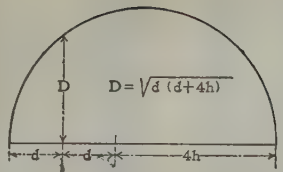


FIG. 2



FIG. 1

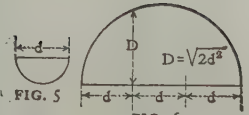


FIG. 5 FIG. 6

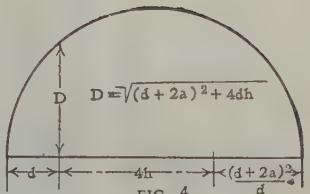


FIG. 4

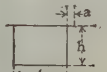


FIG. 3

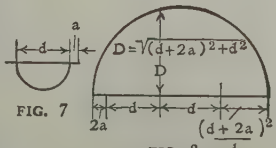


FIG. 7 FIG. 8

$$D = \sqrt{(d + 2a)^2 + d^2}$$

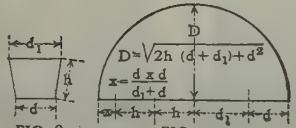


FIG. 9 FIG. 10

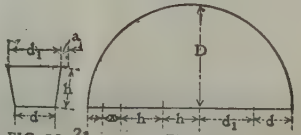


FIG. 11 FIG. 12

Finding the Diameters of Shell Blanks

TABLE OF DIAMETERS OF SHELL BLANKS

THE table shows the diameters of blanks for shells $\frac{1}{4} \times \frac{1}{4}$ inch to 6×6 inches inclusive, by $\frac{1}{4}$ inches. The figures were obtained by the formula given on page 285:

$$D = \sqrt{d(d + 4h)}$$

where,

d = Diameter of finished shell.
h = Height of finished shell.

They were also checked by figuring on the area of the metal.

If it is desired to punch the metal in one or more operations, get the mean height of the shell by the following formula:

$$m = \frac{h\,t}{T}$$

where

m = Mean height of finished shell.
h = Height of finished shell.
t = Thickness of finished shell.
T = Thickness of metal before drawing.

Suppose, for example, a shell 2 inches diameter by 6 inches high; thickness of metal before drawing, 0.040 inch; finish thickness of shell, 0.020 inch. Then

$$m = \frac{h\,t}{T} = \frac{6 \times 0.020}{0.040} = 3 \textit{ inches.}$$

By using this height, from the table we find a shell 2 inches diameter by 3 inches high requires a blank 5.29 inches diameter.

When the shell has rounded corners at the bottom, subtract the radius of the corner from the figures given in the table. Thus, in

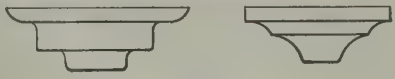


FIG. 13

the last example, suppose the shell to have a radius of $\frac{1}{8}$ inch on the corner; $5.29 - 0.125 = 5.165$ inches, the required diameter of the blanks.

When a shell has a cross-section similar to the ones shown in Fig. 13, the required blank diameter may be calculated by the following formula:

$$d = 1.1284\sqrt{\frac{W}{w\,t}},$$

where

d = Diameter of blank in inches;
W = Weight of shell;
w = Weight of one cubic inch of the metal;
t = Thickness of shell.

Diameter of Blanks for Shells, $\frac{1}{4} \times \frac{1}{4}$ Inch to 6 × 6 Inches

Shell Diameter	Height of Shell											
	1″/4	1″/2	3″/4	1″	1 1/4″	1 1/2″	1 3/4″	2″	2 1/4″	2 1/2″	2 3/4″	3″
				E								
1″	0.56	0.75	0.90	1.03	1.14	1.25	1.35	1.44	1.52	1.60	1.68	1.75
1 1/4″	0.87	1.12	1.32	1.50	1.66	1.80	1.94	2.06	2.18	2.29	2.40	2.50
1 1/2″	1.14	1.44	1.68	1.89	2.08	2.25	2.41	2.56	2.70	2.84	2.97	3.09
1 3/4″	1.41	1.73	2.00	2.24	2.45	2.65	2.83	3.00	3.16	3.32	3.46	3.61
2″	1.68	2.01	2.30	2.56	2.79	3.01	3.21	3.40	3.58	3.75	3.91	4.07
2 1/4″	1.94	2.29	2.60	2.87	3.12	3.36	3.57	3.78	3.97	4.15	4.33	4.50
2 1/2″	2.19	2.56	2.88	3.17	3.44	3.68	3.91	4.13	4.34	4.53	4.72	4.91
2 3/4″	2.45	2.83	3.16	3.46	3.74	4.00	4.24	4.47	4.69	4.90	5.10	5.29
3″	2.70	3.09	3.44	3.75	4.04	4.31	4.56	4.80	5.03	5.25	5.46	5.66
3 1/4″	2.96	3.36	3.71	4.03	4.33	4.61	4.87	5.12	5.36	5.59	5.81	6.02
3 1/2″	3.21	3.61	3.98	4.31	4.62	4.91	5.18	5.44	5.68	5.92	6.15	6.37
3 3/4″	3.46	3.87	4.24	4.58	4.90	5.20	5.48	5.74	6.00	6.25	6.48	6.71
4″	3.71	4.13	4.51	4.85	5.18	5.48	5.77	6.04	6.31	6.56	6.80	7.04
4 1/4″	3.97	4.39	4.77	5.12	5.45	5.77	6.06	6.34	6.61	6.87	7.12	7.36
4 1/2″	4.22	4.64	5.03	5.39	5.73	6.05	6.35	6.64	6.91	7.18	7.44	7.69
4 3/4″	4.47	4.90	5.29	5.66	6.00	6.32	6.63	6.93	7.21	7.48	7.75	8.00
5″	4.72	5.15	5.55	5.92	6.27	6.60	6.91	7.22	7.50	7.78	8.05	8.31
5 1/4″	4.98	5.41	5.81	6.19	6.54	6.87	7.19	7.50	7.79	8.08	8.35	8.62
5 1/2″	5.22	5.66	6.07	6.45	6.80	7.15	7.47	7.78	8.08	8.37	8.65	8.92
5 3/4″	5.48	5.92	6.32	6.71	7.07	7.42	7.75	8.06	8.37	8.66	8.94	9.22
6″	5.73	6.17	6.58	6.97	7.33	7.68	8.02	8.34	8.65	8.95	9.24	9.52
6 1/4″	5.98	6.42	6.84	7.23	7.60	7.95	8.29	8.62	8.93	9.23	9.53	9.81
6 1/2″	6.23	6.68	7.09	7.49	7.86	8.22	8.56	8.89	9.21	9.52	9.81	10.10
6 3/4″	6.48	6.93	7.35	7.75	8.12	8.49	8.83	9.17	9.49	9.80	10.10	10.39

Shell Diameter	Height of Shell										
	3 1/4″	3 1/2″	3 3/4″	4″	4 1/4″	4 1/2″	4 3/4″	5″	5 1/4″	5 1/2″	5 3/4″	6″
1″	1.82	1.89	1.95	2.01	2.08	2.14	2.19	2.25	2.30	2.36	2.41	2.46
1 1/4″	2.60	2.69	2.78	2.87	2.96	3.04	3.12	3.21	3.29	3.36	3.44	3.50
1 1/2″	3.21	3.33	3.44	3.54	3.65	3.75	3.85	3.95	4.04	4.13	4.22	4.31
1 3/4″	3.74	3.87	4.00	4.12	4.24	4.36	4.47	4.58	4.69	4.80	4.90	5.00
2″	4.22	4.37	4.51	4.64	4.77	4.91	5.03	5.15	5.27	5.39	5.50	5.62
2 1/4″	4.66	4.82	4.98	5.12	5.27	5.41	5.55	5.68	5.81	5.94	6.06	6.18
2 1/2″	5.08	5.26	5.41	5.58	5.73	5.88	6.03	6.17	6.31	6.45	6.58	6.71
2 3/4″	5.48	5.66	5.83	6.00	6.16	6.32	6.48	6.63	6.78	6.93	7.07	7.21
3″	5.86	6.05	6.23	6.41	6.58	6.75	6.91	7.07	7.23	7.39	7.54	7.69
3 1/4″	6.22	6.42	6.61	6.80	6.98	7.16	7.33	7.50	7.66	7.82	7.98	8.14
3 1/2″	6.58	6.79	6.99	7.18	7.37	7.55	7.73	7.91	8.08	8.25	8.41	8.58
3 3/4″	6.93	7.14	7.35	7.55	7.75	7.94	8.12	8.31	8.49	8.66	8.83	9.00
4″	7.27	7.49	7.70	7.91	8.11	8.31	8.50	8.69	8.88	9.06	9.24	9.41
4 1/4″	7.60	7.83	8.05	8.26	8.47	8.67	8.87	9.07	9.26	9.45	9.63	9.81
4 1/2″	7.92	8.16	8.38	8.61	8.82	9.03	9.24	9.44	9.63	9.83	10.02	10.20
4 3/4″	8.25	8.49	8.72	8.94	9.17	9.38	9.59	9.80	10.00	10.20	10.39	10.58
5″	8.56	8.81	9.04	9.28	9.50	9.72	9.94	10.15	10.36	10.56	10.76	10.96
5 1/4″	8.87	9.12	9.37	9.60	9.84	10.06	10.28	10.50	10.71	10.92	11.12	11.32
5 1/2″	9.18	9.44	9.69	9.93	10.16	10.40	10.62	10.84	11.06	11.27	11.48	11.69
5 3/4″	9.49	9.75	10.00	10.25	10.49	10.72	10.95	11.18	11.40	11.62	11.83	12.04
6″	9.79	10.05	10.31	10.56	10.81	11.05	11.28	11.51	11.74	11.96	12.18	12.39
6 1/4″	10.08	10.36	10.62	10.87	11.12	11.37	11.61	11.84	12.07	12.30	12.52	12.74
6 1/2″	10.38	10.66	10.92	11.18	11.44	11.69	11.93	12.17	12.40	12.63	12.85	13.08
6″	10.68	10.95	11.23	11.49	11.75	12.00	12.25	12.49	12.73	12.96	13.19	13.42

PUNCH AND DIE ALLOWANCE FOR ACCURATE WORK

In the blanking, perforating and forming of flat stock in the power press for parts of adding machines, typewriters, etc., it is generally desired to make two different kinds of cuts with the dies used. First, to leave the outside of the blank of a semi-smooth finish, with sharp corners, free from burrs, and with the least amount of rounding on the cutting side. Second, to leave the holes and slots that are perforated in the parts as smooth and straight as possible, and

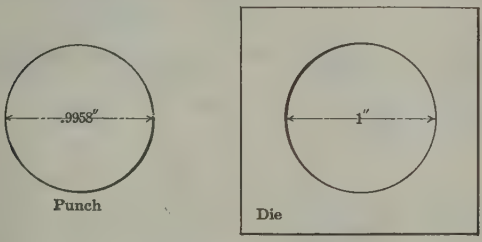


Fig. 14.—Blanking Tools

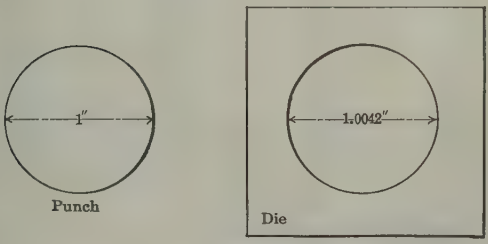


Fig. 15.—Perforating Tools

true to size. The table given is the result of considerable experimenting on this class of work, and has stood the test of years of use since it was compiled.

The die always governs the size of the work passing through it. The punch governs the size of the work that it passes through. In blanking work the die is made to the size of the work wanted and the punch smaller. In perforating work the punch is made to the size of the work wanted and the die larger than the punch. The clearance between the die and punch governs the results obtained.

Figs. 14 and 15 show the application of the table in determining the clearance for blanking or perforating hard rolled steel .060 inch thick. The clearance given in the table for this thickness of metal is .0042, and Fig. 14 shows that for blanking to exactly 1 inch diameter this amount is deducted from the diameter of the punch, while for perforating the same amount is added, as in Fig. 15, to the diameter of the die. For a sliding fit make punch and die .00025 to .0005 inch larger; and for a driving fit make punch and die .0005 to .0015 inch smaller.

TABLE OF ALLOWANCES FOR PUNCH AND DIE FOR DIFFERENT THICKNESS AND MATERIALS

Thickness of Stock Inch	Clearance for Brass and Soft Steel Inch	Clearance for Medium Rolled Steel Inch	Clearance for Hard Rolled Steel Inch
.010	.0005	.0006	.0007
.020	.001	.0012	0014
.030	.0015	.0018	.0021
.040	.002	.0024	.0028
.050	.0025	.003	.0035
.060	.003	.0036	.0042
.070	.0035	.0042	.0049
.080	.004	.0048	.0056
.090	.0045	.0054	.0063
.100	.005	.006	.007
.110	.0055	.0066	.0077
.120	.006	.0072	.0084
.130	.0065	.0078	.0091
.140	.007	.0084	.0098
.150	.0075	.009	.0105
.160	.008	.0096	.0112
.170	.0085	.0102	.0119
.180	.009	.0108	.0126
.190	.0095	.0114	.0133
.200	.010	.012	.014

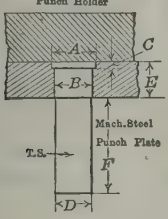
CLEARANCE FOR PUNCHES AND DIES FOR BOILER WORK

THE practice of the Baldwin Locomotive Works on sizes up to $1\frac{1}{4}$ inches is to make the punch $\frac{1}{64}$ inch below nominal size and the die $\frac{1}{64}$ inch above size, which gives $\frac{1}{32}$ inch clearance. Above $1\frac{1}{4}$ inches the punches are made to nominal size and the dies $\frac{1}{32}$ inch large, which allows the same clearance as before. The taper on dies below $1\frac{1}{4}$ inches is 1 inch in 12; on sizes above $1\frac{1}{4}$ inches it is half this or $\frac{1}{2}$ inch in 12 inches.

Types of Punches

Table 1 covers a series of punches for various sizes of pierced holes. The punch bodies at a point immediately under the head are .001 inch large for fitting snugly in the punch plate as indicated. Such punches are readily ground to size and fitted to their places.

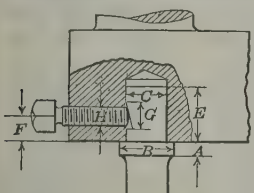
TABLE 1.—PIERCING PUNCHES



Diam. Punch D, Inches	A	B	C	E	F
0–1/4	5/16	.251	3/32	5/8	1 3/4
5/16	7/16	.3135	3/32	5/8	1 3/4
3/8	1/2	.376	3/32	5/8	1 3/4
7/16	9/16	.4385	3/32	5/8	1 3/4
1/2	5/8	.501	3/32	5/8	1 3/4
9/16	11/16	.5035	3/32	5/8	1 3/4
5/8	3/4	.626	3/32	5/8	1 3/4
11/16	13/16	.6885	3/32	5/8	1 3/4
3/4	7/8	.751	3/32	5/8	1 3/4

The punches in Table 2 are useful where they are close to the edge of the punch holder and therefore reached by set screws. The sizes given range from 1/4 inch to 2 inches and they are suited for blanking as well as piercing operations.

TABLE 2.—PIERCING PUNCHES HELD BY SET SCREWS



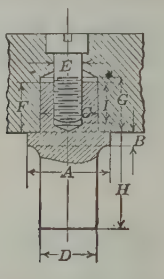
D = Diam., Inches	A	B	C	E	F	G	H
1/4	1/8	5/8	1/2	1	1/2	9/16	3/8
3/8	1/8	5/8	1/2	1	1/2	9/16	3/8
1/2	1/8	3/4	1/2	1	1/2	9/16	3/8
9/16	1/8	3/4	5/8	1 1/4	5/8	9/16	3/8
5/8	1/8	7/8	5/8	1 1/4	5/8	9/16	3/8
3/4	1/8	7/8	5/8	1 1/4	5/8	9/16	3/8
7/8	1/8	1	3/4	1 1/2	3/4	5/8	7/16
1	1/8	1	3/4	1 1/2	3/4	5/8	7/16
1 1/16	3/8	1 1/8	3/4	1 1/2	3/4	5/8	7/16
1 1/4	1/8	1 1/4	1	1 3/4	7/8	1 1/16	1/2
1 1/2	1/8	1 1/2	1	1 3/4	7/8	1 1/16	1/2
1 3/4	1/8	1 3/4	1 1/4	1 7/8	7/8	1 3/16	5/8
2	1/8	2	1 3/8	1 7/8	7/8	1 3/16	5/8

A substantial type of punch for either piercing or blanking is covered in various sizes by Table 3. This construction provides for the securing of the punch in its holder by means of a fillister head screw tapped in from the top as indicated.

PILOTS

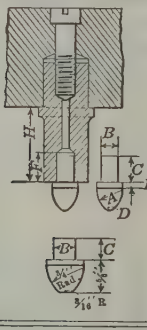
The pilot is inserted in the blanking punch and is made to a long radius, equal at least to the diameter of the pilot body. This

TABLE 3.—PUNCHES HELD BY SCREW TAPPED IN FROM THE TOP



D = Diam. of Punch	A	B	C	E	F	G	H	I
¼	5/8	⅛	½	5/16	1	1⅛	1⅛	5/8
5/16	5/8	⅛	½	5/16	1	1⅛	1⅛	5/8
⅜	5/8	⅛	½	5/16	1	1⅛	1⅛	5/8
7/16	5/8	⅛	½	5/16	1	1⅛	1⅛	5/8
½	5/8	⅛	½	5/16	1	1⅛	1⅛	5/8
9/16	5/8	⅛	½	5/16	1	1⅛	1⅛	5/8
⅝	5/8	⅛	½	5/16	1	1⅛	1⅛	5/8
11/16	5/8	⅛	½	5/16	1	1⅛	1⅛	5/8
¾	5/8	⅛	½	5/16	1	1⅛	1⅛	5/8
13/16	5/8	⅛	½	5/16	1	1⅛	1⅛	5/8
⅞	5/8	⅛	½	5/16	1	1⅛	1⅛	5/8
15/16	1	⅛	½	5/16	1	1⅛	1⅛	5/8
1	1⅛	⅛	½	5/16	1	1⅛	1⅛	5/8
1⅛	1¼	⅛	½	5/16	1	1⅛	1⅛	5/8
1¼	1⅜	5/32	½	5/16	1	1⅛	1⅛	5/8
1⅜	1½	5/32	½	5/16	1	1⅛	1⅛	5/8
1½	1⅝	5/32	½	5/16	1	1⅛	1⅛	5/8
1¾	1⅞	5/32	1¼	5/16	1	1⅛	1⅛	5/8
2	2 1/16	5/32	1⅜	5/16	1	1⅛	1⅛	5/8

TABLE 4.—PILOTS FOR PROGRESSIVE BLANKING PUNCHES



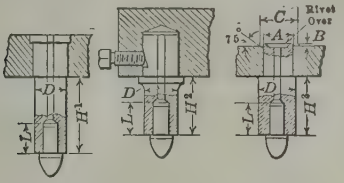
A, Inch	B	C	D	E	F	H
3/16	⅛	5/16	1/32	1/16	7/16	1 3/16
¼	3/16	7/16	1/32	1/16	9/16	1 3/16
5/16	¼	½	1/16	1/16	⅝	1 3/16
⅜	¼	½	1/16	1/16	⅝	1 3/16
7/16	¼	½	1/32	1/16	⅝	1 3/16
½	¼	½	⅛	1/16	⅝	1 3/16
⅝	5/16	9/16	5/32	1/16	1 1/16	1 3/16
11/16	5/16	9/16	Flat end	1/16	1 1/16	1 3/16
¾	⅜	⅝	Flat end	1/16	¾	1 3/16
⅞	⅜	⅝	Flat end	1/16	¾	1 3/16
1	7/16	1 1/16	Flat end	1/16	1 3/16	1 3/16
1 ¼	½	¾	Flat end	1/16	⅞	1 3/16

question of pilots is of interest as they are so extensively used in connection with progressive dies. Table 4 herewith is laid out to cover pilot dimensions for the type of punch which is held by a fillister head screw tapped in from the top of the punch holder. The same dimensions apply also to pilots for the other classes of punches whose proportions are given in Tables 1, 2 and 5, and in all cases the pilots should be ground or otherwise finished on the stem or shank to a press fit in the ends of the blanking punches.

Ordinarily the pilots can be made of drill rod. In the smaller sizes, as indicated in the tables, the point of the pilot is rounded to a definite radius given in Column D, Table 4. For larger sizes of pilots the bottom end is flat, reducing the length accordingly, and the corners are rounded to a radius of 3/16 inch. These proportions are varied where necessary but for a wide range of work they have proved satisfactory.

TABLE 5.—PROGRESSIVE BLANKING PUNCHES WITH PILOTS

For Pilot Dimensions Refer to Table 4
Make L for All Punches Equal to Pilot Shank + 1/8 Inch
(See Table 10 for Pilots)



D = Diam., Inches	H^1	H^2	H^3	A	B	C
1/4	1 13/16	1 3/16				
5/16	1 13/16	1 3/16				
3/8	1 13/16	1 3/16				
7/16	1 13/16	1 3/16				
1/2	1 13/16	1 3/16				
9/16	1 13/16	1 3/16				
5/8	1 13/16	1 3/16	1 3/16	1/2	1/16	5/8
11/16	1 13/16	1 3/16	1 3/16	1/2	1/16	5/8
3/4	1 13/16	1 3/16	1 3/16	1/2	1/16	5/8
7/8	.....	1 3/16	1 3/16	9/16	1/16	11/16
1	.....	1 3/16	1 3/16	5/8	1/16	3/4
1 1/8	.....	1 3/16	1 3/16	3/4	1/16	7/8
1 1/4	.....	1 3/16	1 3/16	7/8	1/16	1
1 1/2	.....	1 3/16	1 3/16	1 1/8	3/32	1 5/16
1 5/8	.....	1 3/16	1 3/16	1 1/4	3/32	1 7/16
1 3/4	.....	1 3/16	1 3/16	1 5/16	3/32	1 7/16
1 7/8	.....	1 3/16	1 3/16	1 5/16	3/32	1 1/2
2	.....	1 3/16	1 3/16	1 3/8	3/32	1 9/16
2 1/8	.....	....	1 3/16	1 3/8	3/32	1 9/16
2 3/8	.....	....	1 3/16	1 1/2	3/32	1 11/16
2 5/8	.....	....	1 3/16	1 3/4	3/32	1 15/16
2 7/8	.....	....	1 3/16	2	3/32	2 3/16

Allowances for Shaving

As for any given material, or grade of stock, the condition of the contour of the blank will vary with the thickness of the metal, the amount left for shaving should likewise vary and with a fair degree of uniformity from the thinner gages to the thick material. Similarly the allowance for any given thickness should vary for soft, half-hard, and hard material. In order to cover these allowances for steel blanks of the three grades noted, Table 6 has been developed and has been given thorough tests in connection with numerous shaving dies operating on different classes of work.

This table covers thicknesses of metal from $\frac{3}{64}$ inch to $\frac{1}{8}$ inch inclusive and also includes allowances for German silver and brass. For the latter two materials, it will be noted, the shaving allowances are double those for steel of the same thickness. Table 7 is arranged to give allowances where two shaving cuts are taken. From the quantities under the heading "Allowances for second shave" it will be seen that the amount left for the second shaving operation is one-half that for the first. Thus in the case of a soft steel blank $\frac{1}{16}$-inch thick requiring two shaving cuts, .003 inch would be allowed on a side for the first shaving die to remove and .0015 inch for the second shaving operation, or a total of .0045 inch on a side or .009 inch over all, the blanking dies being made .009 inch larger than the finished size of the piece.

Table 6.—Amount to Allow on a Side for Shaving Contour where Only One Shave is Taken

Thickness of Blank, Inch	Soft Steel, Inch	Half-hard Steel, Inch	Hard Steel, Inch	German Silver, Inch	Brass, Inch	Thickness of Blank, Inch
$\frac{3}{64}$ (.0468)	.0025	.003	.004	.005	.005	$\frac{3}{64}$ (.0468)
$\frac{1}{16}$ (.0625)	.003	.004	.005	.006	.006	$\frac{1}{16}$ (.0625)
$\frac{5}{64}$ (.0782)	.0035	.005	.006–.007	.007	.007	$\frac{5}{64}$ (.0782)
$\frac{3}{32}$ (.0938)	.004	.006	.007–.008	.008	.008	$\frac{3}{32}$ (.0938)
$\frac{7}{64}$ (.1094)	.005	.007	.009–.011	.010	.010	$\frac{7}{64}$ (.1094)
$\frac{1}{8}$ (.125)	.007	.009	.012–.014	.014	.014	$\frac{1}{8}$ (.125)

TABLE 7.—AMOUNT TO ALLOW ON A SIDE FOR SHAVING CONTOUR WHERE A SECOND SHAVING OPERATION IS USED

Thickness of Blank, Inch	Allowance for First Shave		
	Soft Steel, Inch	Half-hard Steel, Inch	Hard Steel, Inch
3/64 (.0468)	.0025	.003	.004
1/16 (.0625)	.003	.004	.005
5/64 (.078)	.0035	.005	.006 —.007
3/32 (.0938)	.004	.006	.007 —.008
7/64 (.1094)	.005	.007	.009 —.011
1/8 (.125)	.007	.009	.012 —.014

Thickness of Blank, Inch	Allowance for Second Shave		
	Soft Steel Inch	Half-hard Steel, Inch	Hard Steel, Inch
3/64 (.0468)	.00125	.0015	.002
1/16 (.0625)	.0015	.002	.0025
5/64 (.78)	.00175	.0025	.003 —.0035
3/32 (.0938)	.002	.003	.0035—.004
7/64 (1094)	.0025	.0035	.0045—.0055
1/8 (.125)	.0035	.0045	.006 —.007

TABLE 8.—APPROXIMATE PRESSURES IN POUNDS FOR PUNCHING BRASS AND STEEL; FOR 1-INCH DIAMETER OF HOLE

Gage, U. S. Standard Plate		Shearing Strength of Brass per Sq. In. = 35,000 Lb. Shearing Strength of Steel per Sq. In. = 50,000 Lb. Shearing Strength of High-carbon Steel per Sq. In. = 75,000 Lb.		
No.	Thickness	Brass	Steel	High-carbon Steel
28	.015625	1,718	2,454	3,681
27	.0171875	1,870	2,790	3,928
26	.01875	2,067	2,940	4,395
25	.021875	2,408	3,422	5,168
24	.025	2,749	3,927	5,890
23	.028125	3,080	4,396	6,640
22	.03125	3,440	4,914	7,316
21	.034875	3,781	5,385	8,024
20	.0375	4,123	5,890	8,835
19	.04375	4,816	6,876	10,484
18	.05	5,498	7,854	11,781
17	.05625	6,190	8,940	13,236
16	.0625	6,872	9,817	14,726
15	.0703125	7,696	10,990	16,520
14	.078125	8,597	12,246	18,408
13	.09375	10,335	14,765	22,148
12	.109375	11,985	17,110	25,721
11	.125	13,744	19,635	29,452
10	.140625	15,505	22,135	33,040
9	.15625	17,150	24,540	36,810
8	.171875	18,912	27,900	39,280
7	.1875	20,672	29,400	43,950
6	.203125	22,321	31,870	47,900
5	.21875	24,080	34,220	51,680
4	.234375	25,729	36,700	55,224
3	.250	27,490	39,270	58,900
2				
1				

Rule: Multiply thickness of stock by length by shearing strength of material.

TABLE 9.—APPROXIMATE PRESSURE IN POUNDS FOR SHEARING BRASS AND STEEL FOR 1-INCH LENGTH OF CUT

Shearing strength of brass per sq. in. = 35,000 lb.
Shearing strength of steel per sq. in. = 50,000 lb.
Shearing strength of high-carbon steel per sq. in. = 75,000 lb.

Gage, U. S. Standard Plate		Pounds Pressure		
No.	Thickness	Brass	Steel	High-carbon Steel
28	.015625	546	780	1,170
27	.0171875	595	850	1,275
26	.01875	615	940	1,400
25	.021875	770	1,090	1,635
24	.025	875	1,250	1,875
23	.028125	980	1,405	2,100
22	.03125	1,085	1,560	2,340
21	.034375	1,190	1,715	2,550
20	.0375	1,312	1,875	2,812
19	.04375	1,540	2,185	3,280
18	.05	1,750	2,500	3,750
17	.05625	1,960	2,810	4,200
16	.0625	2,187	3,125	4,687
15	.0703125	2,480	3,515	5,250
14	.078125	2,710	3,905	5,850
13	.09375	3,290	4,700	7,050
12	.109375	3,815	5,465	8,200
11	.125	4,375	6,250	9,375
10	.140625	4,935	7,030	10,500
9	.15625	5,460	7,810	11,700
8	.171875	6,020	8,598	12,900
7	.1875	6,562	9,375	14,062
6	.203125	7,075	10,155	15,225
5	.21875	7,667	10,935	16,425
4	.234375	8,190	11,715	17,550
3	.250	8,750	12,500	18,750
2				
1				

Rule: Multiply thickness of stock by length by shearing strength of material.

THE EFFECT OF SHEARED TOOLS

Where the tools are sheared, that is beveled off from one side to the other to give a gradual sloping cutting action, the pressure required is much less than given in the table, and may usually be taken at one-half of the pressures for flat tools for stock not over, say, ¼-inch thick. Beyond that a safer amount would be two-thirds of the pressure necessary for dies without shear.

TABLE 10.—CLEARANCE BETWEEN BLANKING PUNCH AND DIE

Thickness of Stock	Gage						Clearance Between Blanking Punch and Die Based Upon Percentage of Thickness					
	American or Brown & Sharpe		U. S. Standard for Plate		Birmingham or Stubbs							
	No.	Thickness	No.	Thickness	No.	Thickness	5 Per Cent.	6 Per Cent.	7 Per Cent.	8 Per Cent.	10 Per Cent.	12 Per Cent.
	40	.003144										
	39	.003531										
.005	38	.003965					.00025	.0003	.00035	.0004	.0005	.0006
	37	.004453										
	36	.005										
	35	.005614	38	.00625	36	.004						
	34	.006304	37	.006640	35	.005						
	33	.00708	36	.007031	34	.007						
.010	32	.00795	35	.007812	33	.008	.0005	.0006	.0007	.0008	.001	.0012
	31	.008928	34	.008593	32	.009						
	30	.010025	33	.009375	31	.010						
	29	.011257	32	.010156	30	.012						
			31	.010937								
.015	28	.012641			29	.013	.00075	.0009	.00105	.0012	.0075	.0018
	27	.014195	30	.0125	28	.014						
			29	.014062								
	26	.01594	28	.015625	27	.016						
.020	25	.0179	27	.017187	26	.018	.0010	.0012	.0014	.0016	.002	.0024
			26	.01875	25	.020						
	24	.0201	25	.021875	24	.022						

.025	23	.022571	24	.025	23	.025	.00125	.0015	.00175	.0020	.0025	.0030
	22	.025347	23	.028125	22	.028						
.030	21	.028462					.00150	.0018	.0021	.0024	.0030	.0036
	20	.031961	22	.03125	21	.032						
.035	19	.03589	21	.034375	20	.035	.00175	.0021	.00245	.0028	.0035	.0042
.040	18	.040303	20	.0375	19	.042	.002	.0024	.0028	.0032	.004	.0048
.045	17	.045257	19	.04375			.00225	.0027	.00315	.0036	.0045	.0054
.050	16	.05082	18	.050	18	.049	.0025	.0030	.0035	.0040	.0050	.0060
.055	15	.057068	17	.0562			.00275	.0033	.00385	.0044	.0055	.0066
.060					17	.058	.003	.0036	.0042	.0048	.006	.0072
.065	14	.064084	16	.0625	16	.065	.00325	.0039	.00455	.0052	.0065	.0078
.070	13	.071961	15	.070312	15	.072	.0035	.0042	.0049	.0056	.007	.0084
.075							.00375	.0045	.00525	.0060	.0075	.0090
.080	12	.080808	14	.078125			.004	.0048	.0056	.0064	.008	.0096
.085					14	.083	.00425	.0051	.00595	.0068	.0085	.0102
.090	11	.090742					.0045	.0054	.0063	.0072	.009	.0108
.095			13	.09375	13	.095	.00475	.0057	.00665	.0076	.0095	.0114
.100	10	.10189					.005	.0060	.007	.0080	.010	.0120
.105							.00525	.0063	.00735	.0084	.0105	.0126
.110			12	.109375	12	.109	.00550	.0066	.00770	.0088	.011	.0132
.115	9	.11443					.00575	.0069	.00805	.0092	.0115	.0138
.120					11	.120	.006	.0072	.00840	.0096	.012	.0144
.125			11	.125			.00625	.0075	.00875	.0100	.0125	.0150
.130	8	.12849					.00650	.0078	.00910	.0104	.013	.0156
.135					10	.134	.0065	.0081	.00945	.0108	.0135	.0162
.140			10	.140625			.007	.0084	.00980	.0112	.014	.0168
.145	7	.14428					.00725	.0087	.01015	.0116	.0145	.0174
.150					9	.148	.0075	.009	.01050	.0120	.015	.0180
.155							.00775	.0093	.01085	.0124	.0155	.0186
.160	6	.16202	9	.15625			.008	.0096	.01120	.0128	.016	.0192
.165					8	.165	.00825	.0099	.01155	.0132	.0165	.0198
170			8	.171875			.00850	.0102	.01190	.0136	.017	.0204
.175							.00875	.0105	.01225	.0140	.0175	.0210
.180					7	.180	.009	.0108	.01260	.0144	.018	.0216

TABLE 10.—(*Continued*)

Thickness of Stock	Gage						Clearance Between Blanking Punch and Die Based Upon Percentage of Thickness					
	American or Brown & Sharpe		U. S. Standard for Plate		Birmingham or Stubbs							
	No.	Thickness	No.	Thickness	No.	Thickness	5 Per Cent.	6 Per Cent.	7 Per Cent.	8 Per Cent.	10 Per Cent.	12 Per Cent.
.185	5	.18194					.00925	.0111	.01295	.0148	.0185	.0222
.190			7	.1875			.00950	.0114	.01330	.0152	.019	.0228
.195							.00975	.0117	.01365	.0156	.0195	.0234
.200							.0100	.0120	.01400	.0160	.020	.0240
.205	4	.20431	6	.203125	6	.203	.01025	.0123	.01435	.0164	.0205	.0246
.210							.01050	.0126	.01470	.0168	.021	.0252
.215							.01075	.0129	.01505	.0172	.0215	.0258
.220			5	.21875	5	.220	.0110	.0132	.01540	.0176	.022	.0264
.225							.01125	.0135	.01575	.0180	.0225	.0270
.230	3	.22942					.01150	.0138	.01610	.0184	.023	.0276
.235			4	.234375			.01175	.0141	.01645	.0188	.0235	.0282
.240					4	.238	.01200	.0144	.01680	.0192	.024	.0288
.245							.01225	.0147	.01715	.0196	.0245	.0294
.250	2	.25763	3	.250	3	.259	.01250	.0150	.01750	.0200	.025	.0300

Another Table of Clearances Between Punch and Die

Table 10 has been computed to cover clearances for all gages of material in the three gage standards commonly used for sheet metal.

This table has been worked out more in detail to give clearances based upon various percentages of stock thickness ranging from 5 per cent. to 12 per cent. The first column is arranged to advance by increments of .005 inch, and directly opposite, under the respective gage headings, are grouped the actual gage equivalents most closely corresponding to the thickness in the first column.

Of the six columns of clearances, the first three are particularly adapted to very accurate work and small parts especially, 5 per cent. being the allowance computed for brass and soft steel; 6 per cent. for medium rolled steel; and 7 per cent. for hard rolled steel. Similarly, the other three columns cover the general run of work where a little more clearance is permissible, 8 per cent. being here allowed for brass and soft steel; 10 per cent. for medium rolled steel; and 12 per cent. for hard rolled steel.

These clearances apply to piercing dies as well as to dies for blanking.

Table of Die Clearances or Relief

It is of value to know how much increase in blanking die size occurs as the face is ground down in resharpening. The table has been worked out to cover various angles of taper besides the conventional slope of ½ degree on a side. While the half-degree taper relief or clearance is almost universally used for ordinary dies, there are special instances where this angle has been exceeded, especially with certain piercing and perforating dies.

While, ordinarily, the angle of ½ degree on a side will allow of the free discharge of the slugs from perforated blanks, such materials as aluminum and similarly soft metals sometimes produce slugs that in the small sizes, particularly, tend to swage into the walls of the piercing die when forced down by the punch and because of the expanding action upon their limited areas, these slugs may then stick, and stack up and, becoming welded together, are likely to cause the punch to break or the die to become chipped around the edges of the small hole.

The table is arranged to show the additional amount at each side of a die for every ten-thousandth ground off of its top face.

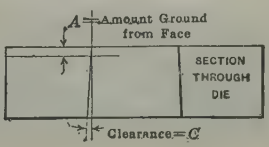
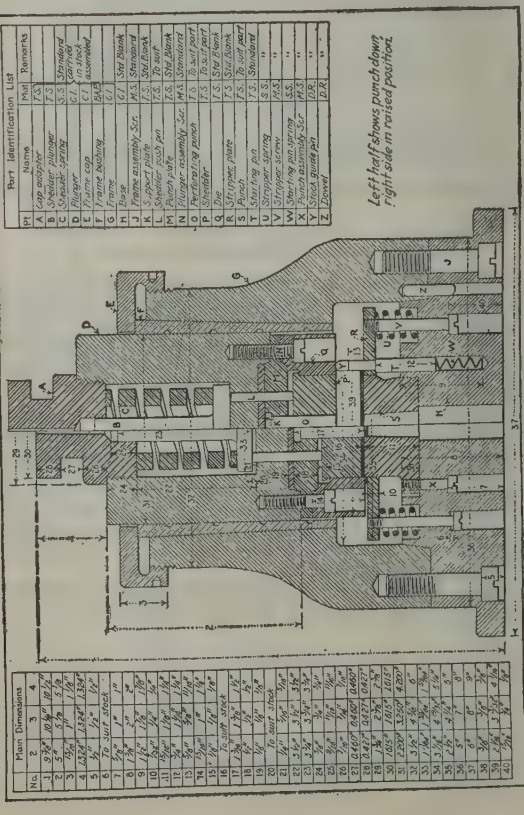


Fig. 17

Typical Double-acting Sub-press

In Fig. 16 is shown a typical double-acting sub-press with a list of parts and the dimensions of each. The punch blanks and punches the piece at the same operation. A little study of the identification list on the right will make the operation clear. This is helped by the left side being shown in the lower position.



Part Identification List

Pt	Name	Mat	Remarks
A	Cap adaptor	T.S.	
B	Shedder plunger	T.S.	
C	Shedder spring	S.S.	Standard
D	Plunger	C.I.	Carried
E	Plunger cap	C.I.	in stock
F	Frame bedding	B.M.	assembled
G	Frame	C.I.	
H	Base	C.I.	Std Blank
J	Frame assembly Scr.	M.S.	Standard
K	Stripper plate	T.S.	Std Blank
L	Shedder knock pin	T.S.	Std Blank
M	Punch plate	T.S.	Std Blank
N	Plunger assembly Scr.	M.S.	Standard
O	Perforator punches	T.S.	To suit part
P	Shedder	T.S.	To suit part
Q	Die	T.S.	Std Blank
R	Stripper plate	T.S.	Std Blank
S	Stop pin	T.S.	To suit part
T	Starting pin	T.S.	Standard
U	Stripper spring	S.S.	"
V	Stripper screw	M.S.	"
W	Starting pin spring	S.S.	"
X	Punch assembly Scr.	M.S.	"
Y	Work gauge pin	T.S.	"
Z	Dowel pin	D.R.	"

Main Dimensions

No.	2	3	4
1	2 3/4"	10 1/8	11 1/8
2	3 3/4"	11 1/8	12 1/8
3	5/16"	1"	1 1/8"
4	13/64"	13/64"	13/64"
5	1/2"	1/2"	1/2"
6	To suit stock		
7	1/2"	1"	1"
8	1 1/2"	1 1/2"	1 1/2"
9	1 1/2"	1 1/2"	1 1/2"
10	1/2"	1/2"	1/2"
11	13/64"	13/64"	13/64"
12	3/4"	1 1/8"	1 1/8"
13	3/4"	1 1/8"	1 1/8"
14	1/16"	1/16"	1/16"
15	3/4"	1 1/8"	1 1/8"
16	To suit stock		
17	1 3/8"	1 1/2"	1 1/2"
18	1/2"	1/2"	1/2"
19	1/2"	1/2"	1/2"
20	To suit stock		
21	21/64"	21/64"	21/64"
22	1 1/4"	1 3/4"	1 3/4"
23	1 1/4"	1 3/4"	1 3/4"
24	3/4"	1 1/8"	1 1/8"
25	1/2"	1/2"	1/2"
26	1/2"	1/2"	1/2"
27	21/64"	21/64"	21/64"
28	1 3/4"	2 3/8"	2 3/8"
29	1 3/4"	2 3/8"	2 3/8"
30	1065	1615	1615
31	1230	1350	4230
32	3/8"	1/2"	1/2"
33	1 1/4"	1 3/4"	1 3/4"
34	1 1/4"	1 3/4"	1 3/4"
35	1 1/4"	1 3/4"	1 3/4"
36	5"	7"	7"
37	6"	8"	8"
38	3/4"	1 1/8"	1 1/8"
39	1/4"	1/4"	1/4"
40	1/8"	1/8"	1/8"

FIG. 16.—Part List and Main Dimensions Sub-press Assembling Diagrams

TABLE OF DIE CLEARANCES OR RELIEF

A Amount Ground From Face of Die in Thousandths	*C* Clearance in Thousandths Corresponding to Degrees on Each Side				
Inch	½ Degree	1 Degree	1½ Degrees	2 Degrees	2½ Degrees
.010	.000087	.000175	.000262	.000349	.000437
.020	.000175	.000350	.000524	.000698	.000873
.030	.000241	.000525	.000786	.001047	.001310
.040	.000378	.000700	.001048	.001396	.001746
.050	.000437	.000875	.001310	.001745	.002183
.060	.000524	.001050	.001572	.002094	.002620
.070	.000611	.001225	.001834	.002443	.003016
.080	.000698	.001400	.002096	.003092	.003493
.090	.000776	.001575	.002358	.003141	.003929
.100	.000870	.001750	.002620	.003493	.004370
.110	.000960	.001925	.002882	.003839	.004803
.120	.001047	.002100	.003144	.004188	.005239
.130	.001135	.002275	.003406	.004537	.005677
.140	.001222	.002450	.003668	.004886	.006112
.150	.001309	.002625	.003930	.005235	.006549
.160	.001417	.002800	.004192	.005584	.006986
.170	.001484	.002975	.004554	.005933	.007422
.180	.001571	.003150	.004712	.006282	.007859
.190	.001658	.003325	.004978	.006631	.008295
.200	.001746	.003500	.005240	.006980	.008732
.210	.001827	.003675	.005502	.007329	.009169
.220	.001914	.003850	.005764	.007678	.009605
.230	.002001	.004025	.006026	.008027	.010042
.240	.002088	.004200	.006288	.008376	.010478
.250	.002175	.004375	.006550	.008725	.010915

This is much more than the average amount removed in one grinding, but it is a convenient increment to work from and the quantities in the columns that follow are very readily modified to correspond to any specified amount taken off the die face in the grinding operation.

Consider the half-degree column: The increase at each side of the die is entirely negligible when the first .010 inch has been ground from the face, and only after the die has been ground down .120 inch or almost ⅛ inch does the diameter of the die become .001 inch greater on each side or .002 inch more over all.

LUBRICANT FOR PRESS TOOLS

ALTHOUGH there are some shops in which no lubricant is used when working sheet metal, and where good results are obtained, still it is best to use a lubricant on all classes of sheet-metal work.

For all cutting dies on brass and steel a heavy animal oil is best. Pure lard oil is very satisfactory, although expensive.

When punching copper, or German silver, a thin coating of lard oil or sperm oil should be spread over the sheets or strips before punching. A good way to do this evenly is to coat one sheet thickly and then feed it through a pair of rolls, after which a number of other sheets may be run through the rolls and thus coated evenly For drawn work this method of coating the sheets from which the shells are to be drawn will be found to be the best, as the coating of oil on the stock will be very thin and it will not be found necessary to clean the shells afterward, the oil having disappeared during the blanking and drawing process. When oil is applied with a pad or brush the coating will be so thick that it will be necessary to clean the article produced.

Drawing Steel Shells

In drawing steel shells a mixture of equal parts of oil and black lead is very useful, and while it may be used warm it does not affect the work as much as the speed of the drawing press does; the thicker the stock the slower must be the speed of the punch. A heavy grease with a small proportion of white lead mixed in with it is also recommended for this purpose.

If the drawing die is very smooth and hard at the corner of the "draw," or edge of the die, the liability of clogging will be reduced to a minimum. Often it will help to give to the die a lateral polish by taking a strip of emery cloth and changing the grain of the polish from circular to the same direction as the drawing.

Lubricants for Brass

For drawing brass or copper a clean soap water is considered most satisfactory. One of the largest brass firms in this country uses a preparation made by putting 15 pounds of Fuller's soap in a barrel of hot water, and boiling until all the lumps are dissolved. This is used as hot as possible. If the work is allowed to lie in the water until a slime has formed on the shell it will draw all the better. A soap that is strong in resin or potash will not give good results.

In drawing zinc the water should be hot, or the percentage of broken shells will be large.

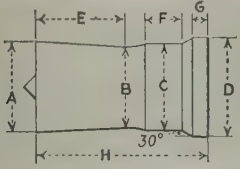
Aluminum is an easy metal to draw, but it hardens up very quickly. For lubricants lard oil, melted Russian tallow and vaseline are all good. The lubricant should be applied to both sides of the metal.

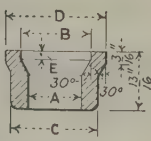
Lubrication for Hot Dies

The life of hot dies, either for hot pressing or die casting, is directly affected by the lubricant used. Numerous experiments indicate that 80 per cent mutton tallow and 20 per cent medium mineral lubricating oil give best results. Mixed at 150 degrees Fahr. and allowed to cool it is about the consistency of soft soap and is applied with a swab. It works well on either die-casting or hot-pressing dies, but only lasts about 10 per cent as long in the die-casting dies. Dies without lubricant lasted only 2 per cent as long as lubricated dies.

U. S. Navy Standard Punches

All punches and dies must be capable of punching 5,000 holes in medium steel plate, $\frac{1}{8}$ inch less than the punch diameter, without regrinding. The proportions are shown in the table below:



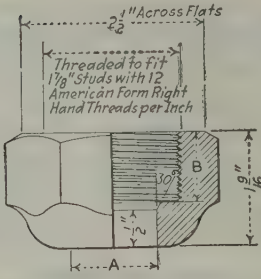


(Dimensions in Inches)

Nominal Size	A	B Minimum	B Maximum	C	D	E	F	G	H
$\frac{7}{32}$	$\frac{7}{32}$	0.175	0.205	$\frac{3}{4}$	1	$\frac{15}{32}$	1	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{1}{4}$	$\frac{1}{4}$	0.203	0.234	$\frac{3}{4}$	1	$\frac{3}{8}$	1	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{9}{32}$	$\frac{9}{32}$	0.288	0.325	$\frac{3}{4}$	1	$\frac{27}{64}$	1	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{5}{16}$	$\frac{5}{16}$	0.317	0.356	$\frac{3}{4}$	1	$\frac{15}{32}$	1	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{11}{32}$	$\frac{11}{32}$	0.373	0.416	$\frac{3}{4}$	1	$\frac{11}{16}$	1	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{3}{8}$	$\frac{3}{8}$	0.430	0.477	$\frac{3}{4}$	1	$\frac{3}{4}$	1	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{13}{32}$	$\frac{13}{32}$	0.486	0.537	$\frac{3}{4}$	1	$\frac{13}{16}$	1	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{7}{16}$	$\frac{7}{16}$	0.543	0.598	$\frac{3}{4}$	1	$\frac{7}{8}$	1	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{15}{32}$	$\frac{15}{32}$	0.599	0.658	$\frac{3}{4}$	1	$\frac{15}{16}$	1	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{1}{2}$	$\frac{1}{2}$	0.656	0.719	$1\frac{1}{32}$	$1\frac{3}{8}$	1	$\frac{1}{2}$	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{17}{32}$	$\frac{17}{32}$	0.713	0.779	$1\frac{1}{32}$	$1\frac{3}{8}$	$1\frac{1}{16}$	$\frac{1}{2}$	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{9}{16}$	$\frac{9}{16}$	0.770	0.840	$1\frac{1}{32}$	$1\frac{3}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{3}{16}$	$2\frac{1}{4}$
$\frac{19}{32}$	$\frac{19}{32}$	0.826	0.900	$1\frac{1}{32}$	$1\frac{3}{8}$	$1\frac{3}{16}$	$\frac{1}{2}$	$\frac{3}{16}$	$2\frac{1}{4}$
1	1	0.883	0.961	$1\frac{1}{32}$	$1\frac{3}{8}$	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{16}$	$2\frac{1}{4}$
$1\frac{1}{16}$	$1\frac{1}{16}$	0.945	1.023	$1\frac{1}{32}$	$1\frac{3}{8}$	$1\frac{5}{16}$	$\frac{1}{2}$	$\frac{3}{16}$	$2\frac{1}{4}$
$1\frac{1}{8}$	$1\frac{1}{8}$	1.008	1.086	$1\frac{1}{32}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{16}$	$2\frac{1}{4}$
$1\frac{3}{16}$	$1\frac{3}{16}$	1.070	1.148	$1\frac{1}{32}$	$1\frac{3}{8}$	$1\frac{7}{16}$	$\frac{1}{2}$	$\frac{3}{16}$	$2\frac{1}{4}$
$1\frac{1}{4}$	$1\frac{1}{4}$	1.133	1.211	$1\frac{1}{32}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{16}$	$2\frac{1}{4}$
Tolerances (all sizes)	$\begin{cases} +0.005 \\ -0.005 \end{cases}$				$\begin{cases} +0.005 \\ -0.005 \end{cases}$				$\begin{cases} +0.000 \\ -0.062 \end{cases}$

U. S. Navy Bushings for Punches
(Dimensions in Inches)

	Dimensions	Tolerances Plus	Tolerances Minus
A	0.757	0.005	0.000
B	1.010	0.010	0.000
C	1.219	0.005	0.005
D	1.375	0.005	0.005
E	0.125	0.031	0.000



U. S. Navy Coupling Nuts for Punches
(Dimensions in Inches)

Coupling Nut No.	A		B	
	Minimum	Maximum	Minimum	Maximum
1	1.230	1.240	0.875	1.000
2	1.570	1.580	0.875	1.000

Note.—No. 1 coupling nuts are for use in connection with punches up to and including $1\frac{3}{16}$ inches in diameter; No. 2 are for punches $1\frac{1}{4}$ inches in diameter.

Pressure Required for Shearing or Punching

$$\frac{\text{Total length of cut in inches} \times \text{Tensile strength of material in tons}}{\text{Thickness of metal in parts of inches}} = \text{Pressure}$$

Example.—Total length of cut = 20 inches. Tensile strength, 30 tons. Thickness, $\frac{1}{4}$ inch. $20 \times 30 = 600 \div 4 = 150$ tons. Or Tensile strength ÷ thickness × length of cut gives same result.

Power Required for Punching and Shearing

Experiments tend to show that, with steel plates of 60,000 pounds tensile strength, the metal is all sheared when the punch has passed one-third through the plate. The following formula by L. R. Pomeroy takes this into account and also allows the motor an efficiency of 80 per cent and the punching machine 75 per cent.

When T = full thickness of plate.
D = diameter of hole punched.
N = number of holes punched per minute.
P = horse-power required to drive machine.

$$P = \frac{T^2 \times D \times N}{3.78}.$$

Taking a $\frac{1}{2}$-inch hole in a $\frac{1}{2}$-inch plate, the power required to punch 30 per minute would be

$$\frac{\frac{1}{2} \times \frac{1}{2} \times 30}{3.78} = \frac{3.75}{3.78} \text{ or about 1 horse-power.}$$

Pressure required for shearing = length of cut × thickness in inches × shearing strength of material. Dies with "shear" reduce this one-third to one-half.

A simple rule is: Multiply the length of the cut by the tensile strength of the material, in *tons*. This gives the pressure required to punch a 1-inch plate. Divide by the thickness of the plate in inches for pressure necessary, *i.e.*, if plate is $\frac{1}{8}$ inch thick divide by 8, if $\frac{1}{16}$ inch thick divide by 16, etc.

Strength of Punch Press Shaft and Housing

A similar rule for the strength of a crankshaft of not over 4-inch throw, is: Square the diameter of the shaft and multiply by $3\frac{1}{2}$. By this rule, a 5-inch shaft with a throw not over 4 inches withstood a pressure of $5 \times 5 \times 3\frac{1}{2} = 87\frac{1}{2}$ tons.

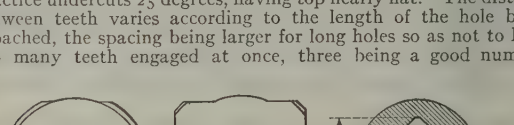
In designing the housing, allow 1 square inch of area for each ton of pressure and make the housing 25 per cent stronger than the shaft.

These figures are for determining whether presses are strong enough for the work rather than for designing.

BROACHES AND BROACHING

Broaching is being used more and more to finish holes and even for slots and the outside of pieces of work. In most cases it is used to change a round hole to a square or other shape, such as the four, six or ten key ways, or splines, used in automobile transmission.

The chip cut by each tooth varies from 0.001 to 0.007 inch, according to the material being cut and the accuracy required. The teeth are usually undercut from 6 to 10 degrees to give a curl to the chip, while the top clearance is about 30 degrees. Some English practice undercuts 25 degrees, having top nearly flat. The distance between teeth varies according to the length of the hole being broached, the spacing being larger for long holes so as not to have too many teeth engaged at once, three being a good number.



The First Chip | The Last Chip | Section of Broached Hole

FIG. 1

In broaching square holes from the round, or in other cases where there is a decided change of shape, the first teeth take the widest cut as at *A*, Fig. 1. This evens up the work of the different teeth as to the length of surface cut as the hole approaches a square as seen at *B*.

The blank for the cutting part of each broach is first turned taper by an amount equal to the total cut of the teeth. The tool spaces are cut about $\frac{1}{2}$ inch apart and about $\frac{3}{32}$ inch deep, this depending on the diameter of the broach, as it must not be unduly weakened; it is then milled $\frac{15}{16}$ inch square as shown. The longer the hole the more chip room must be provided.

Where the hole or other surface to be broached is short, the teeth are often cut on an angle to give a shearing cut. This is also done to prevent chatter at times, another remedy being to space the teeth unevenly as with reamers.

The solid broach is used more than any other. But as tool steel is apt to spring in hardening, and to break out teeth at times, some use built-up or sectional broaches, especially on large work where

the solid broach costs heavily. Some use low carbon steel, case hardened. These sectional broaches are made in a variety of ways, Fig. 2 showing examples where the sections are practically disks held on a central arbor. In some cases several teeth are made on one section. This is for broaching internal gears having 66 teeth, 20 diametral pitch and $\frac{1}{2}$ inch face. Each tooth cuts 0.006, the last three teeth being straight to insure the size being accurate.

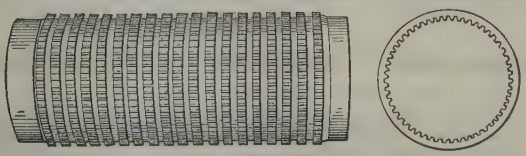


FIG. 2

BROACHING ROUND HOLES

Round holes have been broached instead of reamed in some places for many years and the practice is growing. It was formerly confined to soft metal, such as shaft bearings, but is now being made to cover all the metals, in some few cases broaching from a cored hole. For small work a small arbor press with a sort of sub-press can be used to advantage. For larger work the arbor press operated by power is very good and of course the regular broaching machine can be used in any case. These are for "push" broaching.

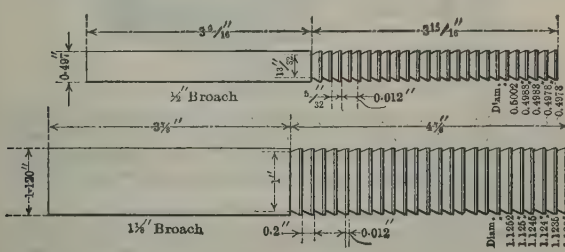


FIG. 3

Two broaches used in one shop are shown in Fig. 3, other sizes can be made in proportion. These were used in a hand arbor press. The first 5 or 6 teeth do most of the cutting as these broaches only finish the holes instead of reaming. In some cases with broaches for soft metal bearings and even in cast iron, the large end is left plain or with buttons and a trifling amount larger than the last tooth. It

then acts as a burnisher and compresses the metal. This requires a large amount of power.

In broaching round holes in cast iron, the broach was made from 0.0002 to 0.0003 inch larger than the nominal size and the land was 0.012 as shown. The holes were drilled close to size so as to leave very little work for the broach. In this case about 0.002 inch was left for broaching.

Push broaches are usually short, being from 6 to 12 inches long.

TO SAVE TIME IN BROACHING OUT SQUARE HOLES

The fit on a square shaft depends almost entirely on the flat surfaces at or near the corners. With this in mind, it is an economy to bore or drill the round hole in the gear slightly larger than the diameter across the flats of the squared shaft, as shown in Fig. 4.

Taking a $1\frac{1}{4}$-inch square shaft and boring the hole $\frac{1}{16}$ inch larger or $1\frac{5}{16}$ inches in diameter, we see in the illustration exactly what this

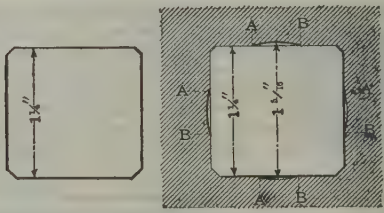


FIG. 4

would mean. The amount of metal to be cut out would be materially reduced, the portion A to B not being touched by the broach in any way. Yet the remaining surface in the corners would be ample to carry all the load and the clearance A to B would allow the best of lubrication.

The center relief, as shown, gives considerable added chip space as well as reduces the amount of chip, thus allowing a heavier chip per tooth. This may either reduce the length of the broach or allow a longer hole (such as two holes at once) to be broached with the same length of broach.

The set of 7 broaches shown in Fig. 5 show the practice of the Brown & Sharpe Mfg. Co. in making gears having square holes. The gears are of a tough alloy steel making the 7 necessary to secure an accurate hole of $1\frac{1}{4}$ inches across the flats. Each broach is $30\frac{1}{2}$ inches long, the cutting portion being only $17\frac{1}{2}$ inches. The method of holding the shank can be readily seen.

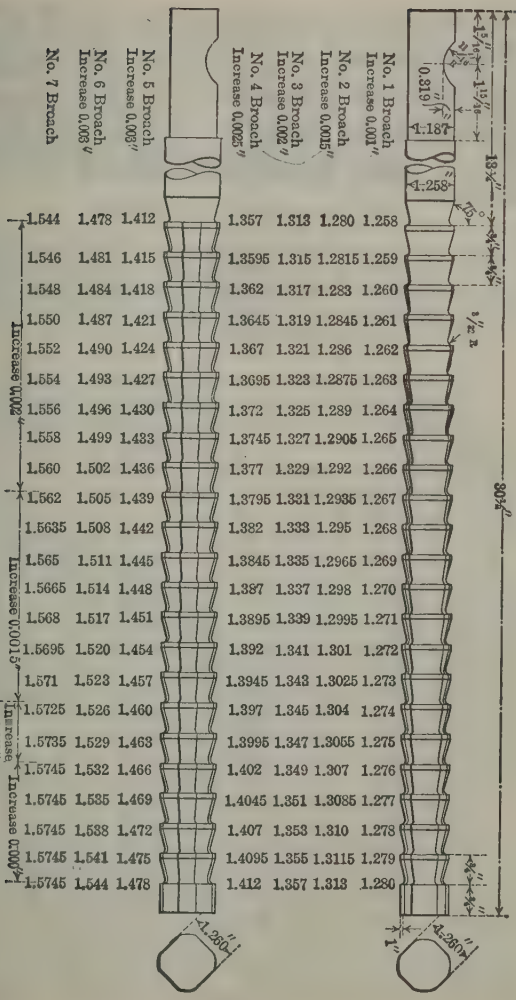

No. 7 Broach
No. 6 Broach Increase 0.003"
No. 5 Broach Increase 0.003"
No. 4 Broach Increase 0.0025"
No. 3 Broach Increase 0.002"
No. 2 Broach Increase 0.0015"
No. 1 Broach Increase 0.001"
1.544 1.478 1.412 1.357 1.313 1.280 1.258
1.546 1.481 1.415 1.3595 1.315 1.2815 1.259
1.548 1.484 1.418 1.362 1.317 1.283 1.260
1.550 1.487 1.421 1.3645 1.319 1.2845 1.261
1.552 1.490 1.424 1.367 1.321 1.286 1.262
1.554 1.493 1.427 1.3695 1.323 1.2875 1.263
1.556 1.496 1.430 1.372 1.325 1.289 1.264
1.558 1.499 1.433 1.3745 1.327 1.2905 1.265
1.560 1.502 1.436 1.377 1.329 1.292 1.266
1.562 1.505 1.439 1.3795 1.331 1.2935 1.267
1.5635 1.508 1.442 1.382 1.333 1.295 1.268
1.565 1.511 1.445 1.3845 1.335 1.2965 1.269
1.5665 1.514 1.448 1.387 1.337 1.298 1.270
1.568 1.517 1.451 1.3895 1.339 1.2995 1.271
1.5695 1.520 1.454 1.392 1.341 1.301 1.272
1.571 1.523 1.457 1.3945 1.343 1.3025 1.273
1.5725 1.526 1.460 1.397 1.345 1.304 1.274
1.5735 1.529 1.463 1.3995 1.347 1.3055 1.275
1.5745 1.532 1.466 1.402 1.349 1.307 1.276
1.5745 1.535 1.469 1.4045 1.351 1.3085 1.277
1.5745 1.538 1.472 1.407 1.353 1.310 1.278
1.5745 1.541 1.475 1.4095 1.355 1.3115 1.279
1.5745 1.544 1.478 1.412 1.357 1.313 1.280
Increase 0.002"
Increase 0.0015"
Increase 0.001"
Increase 0.002"
0.819"
1.187
1.258
75°
1/2" R
30½"
1.260"
1.260"
1"

FIG. 5

The present practice in transmission gears is to use shafts having six splines, the holes being broached in the same way as the square holes referred to on pages 428–430. The chip per tooth is approximately the same, the shape of the broach being made to conform to that of the splines used. Standard splines are shown on page 795.

Pull broaching machines are also made double, to carry two broaches and finish two holes at once. Both screw and hydraulic feed are used. Some push broaching machines are hydraulic but more are mechanical. Multiple push broaching machines have also been built.

BOLTS, NUTS AND SCREWS

STANDARD BOLTS AND NUTS

Bolts, nuts and screws are all being changed to conform to practical standards and to reduce odd wrench sizes wherever advisable. The following pages show the sizes recommended and in some cases retain the old tables. It will be noted that tolerances are now given for bolt heads as well as for the threads.

STRENGTH OF STANDARD BOLTS FROM $\frac{1}{4}$ TO 3″ DIAMETER

Bolt		Areas		Tensile Strength		Shearing Strength			
						Full Bolt		Bottom of Thread	
Diameter of Bolt	No. of Threads per Inch	Full Bolt	Bottom of Thread	At 12,500 lbs. per Sq. In.	At 17,500 lbs. per Sq. In.	At 7,500 lbs. per Sq. In.	At 10,000 lbs. per Sq. In.	At 7,500 lbs. per Sq. In.	At 10,000 lbs. per Sq. In.
$\frac{1}{4}$	20	.049	.027	340	470	380	490	200	270
$\frac{5}{16}$	18	.077	.045	570	790	580	770	340	450
$\frac{3}{8}$	16	.110	.068	850	1,190	830	1,100	510	680
$\frac{7}{16}$	14	.150	.093	1,170	1,630	1,130	1,500	700	930
$\frac{1}{2}$	13	.196	.126	1,570	2,200	1,470	1,960	940	1,260
$\frac{9}{16}$	12	.248	.162	2,030	2,840	1,860	2,480	1,220	1,620
$\frac{5}{8}$	11	.307	.202	2,520	3,530	2,300	3,070	1,510	2,020
$\frac{11}{16}$	10	.442	.302	3,770	5,290	3,310	4,420	2,270	3,020
$\frac{3}{4}$	9	.601	.419	5,240	7,340	4,510	6,010	3,150	4,190
1	8	.785	.551	6,890	9,640	5,890	7,850	4,130	5,510
$1\frac{1}{8}$	7	.994	.693	8,660	12,130	7,450	9,940	5,200	6,930
$1\frac{1}{4}$	7	1.227	.890	11,120	15,570	9,200	12,270	6,670	8,900
$1\frac{3}{8}$	6	1.485	1.054	13,180	18,450	11,140	14,850	7,910	10,540
$1\frac{1}{2}$	6	1.767	1.294	16,170	22,640	13,250	17,670	9,700	12,940
$1\frac{5}{8}$	$5\frac{1}{2}$	2.074	1.515	18,940	26,510	15,550	20,740	11,360	15,150
$1\frac{3}{4}$	5	2.405	1.745	21,800	30,520	18,040	24,050	13,080	17,440
$1\frac{7}{8}$	5	2.761	2.049	25,610	35,860	20,710	27,610	15,370	20,490
2	$4\frac{1}{2}$	3.142	2.300	28,750	40,250	23,560	31,420	17,250	23,000
$2\frac{1}{4}$	$4\frac{1}{2}$	3.976	3.021	37,770	52,870	29,820	39,760	22,660	30,210
$2\frac{1}{2}$	4	4.909	3.716	46,450	65,040	36,820	49,090	27,870	37,160
$2\frac{3}{4}$	4	5.940	4.620	57,750	80,840	44,580	59,400	34,650	46,200
3	$3\frac{1}{2}$	7.069	5.428	67,850	94,990	53,020	70.690	40,710	54,280

A.S.M.E. STANDARD PROPORTIONS OF MACHINE SCREWS

THE diagram and tables herewith show the proportions of machine screws as recommended by the committee of the American Society of Mechanical Engineers on Standard Proportions for Machine Screws, the report of this committee being adopted by the Society at its spring meeting, 1907.

The included angle is 60 degrees, and the flat at top and bottom of thread is one-eighth of the pitch for the basic or standard diameter. There is a uniform increment of 0.013 inch, between all sizes from 0.06 to 0.19 (numbers 0 to 10 in the tables which follow) and of 0.026 inch in the remaining sizes. This change has been made in the interest of simplicity and because the resulting pitch diameters are more nearly in accord with the pitch diameters of screws in present use.

The pitches are a function of the diameter as expressed by the formula

$$\text{Threads per inch} = \frac{6.5}{D + 0.02},$$

with the results given approximately, so as to avoid the use of fractional threads.

The diagram shows the various sizes for both 16 and 72 threads per inch, and shows, among other things, the allowable difference in the flat surface, between the maximum tap and the minimum screw, this variation being from one-eighth to one sixteenth.

The minimum tap conforms to the basic standard in all respects, except diameter. The difference between the minimum tap and the maximum screw provides an allowance for error in pitch and for wear of tap in service.

The form of tap threads shown is recommended as being stronger and more serviceable than the so-called V-thread, but as some believe a strict adherence to the form shown might add to the cost of small taps, they have decided that taps having the correct angle and pitch diameter are permissible even with the V-thread.

The tables given by the committee were combined into the present compact form by the Corbin Screw Corporation.

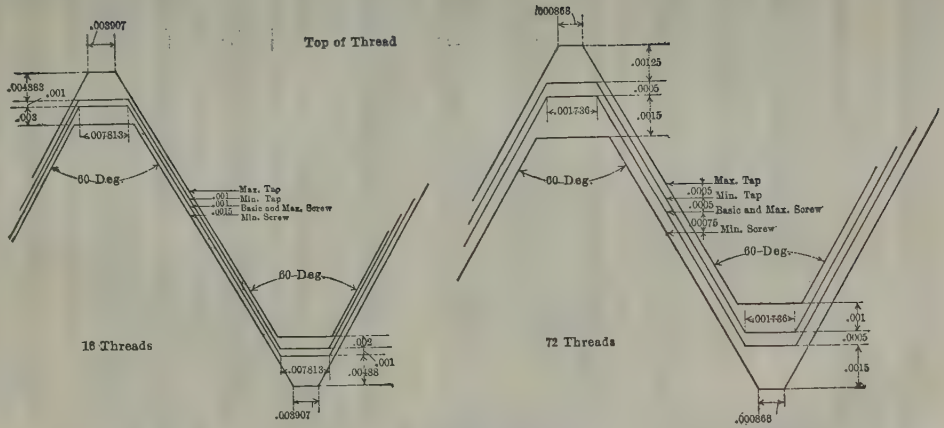
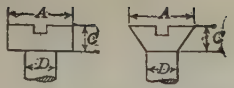


Diagram Showing Form of Basic Maximum and Minimum Screw and Tap Threads
A. S. M. E. Machine Screw Standard



Combined Table of Drill Sizes of A. S. M. E. Screws

This table saves time and trouble in referring back and forth to tables to find either a tap or a body drill size for a certain size of screw.

Drill Sizes for A. S. M. E. Machine Screws

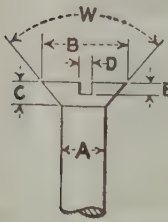
No. of Screw	No. of Threads	Diam. of Screw	No. of Tap Drill or Letter	Tap-Drill Diam.	No. or Letter of Body Drill	Body-Drill Diam.	Fillister Head A	Fillister Head C	No. or Letter of Drill	Diam. of Drill	Flat Head A	Flat Head C	No. or Letter of Drill	Diam. of Drill
0	80	.060	3/64	.0468	52	.0635	.0894	.0376	43	.089	.112	.029	33	.113
1	72	.073	53	.0595	49	.073	.1107	.0461	34	.111	.138	.037	28	.1405
*1	64	.073	54	.055	49	.073	.1107	.0461	34	.111	.138	.037	28	.1405
2	64	.086	50	.070	44	.086	.132	.0548	29	.136	.164	.045	19	.166
*2	56	.086	51	.067	44	.086	.132	.0548	29	.136	.164	.045	19	.166
3	56	.099	45	.082	39	.0995	.153	.0633	23	.154	.190	.052	11	.191
*3	48	.099	47	.0785	39	.0995	.153	.0633	23	.154	.190	.052	11	.191
4	48	.112	43	.089	33	.113	.1747	.0719	16	.177	.216	.060	2	.221
*4	40	.112	44	.086	33	.113	.1747	.0719	16	.177	.216	.060	2	.221
*4	36	.112	45	.082	33	.113	.1747	.0719	16	.177	.216	.060	2	.221
5	44	.125	37	.1044	30	.1285	.196	.0805	9	.196	.242	.067	C	.242
*5	40	.125	38	.1015	30	.1285	.196	.0805	9	.196	.242	.067	C	.242
*5	36	.125	40	.098	30	.1285	.196	.0805	9	.196	.242	.067	C	.242
6	40	.138	33	.113	28	.1405	.217	.089	2	.221	.262	.075	H	.266
*6	36	.138	34	.111	28	.1405	.217	.089	2	.221	.262	.075	H	.266
*6	32	.138	40	.098	28	.1405	.217	.089	2	.221	.262	.075	H	.266
7	36	.151	31	.120	24	.152	.2386	.0976	B	.238	.294	.082	M	.295
*7	32	.151	31	.120	24	.152	.2386	.0976	B	.238	.294	.082	M	.295
*7	30	.151	32	.116	24	.152	.2386	.0976	B	.238	.294	.082	M	.295
8	36	.164	29	.136	19	.166	.2599	.1062	G	.261	.320	.090	P	.323

*8	30	.164	30	.1285	19	.166	.2599	.1062	G	.261	.320	.090	P	.323
9	32	.177	26	.147	16	.177	.2813	.1148	K	.281	.346	.097	S	.348
*9	30	.177	27	.144	16	.177	.2813	.1148	K	.281	.346	.097	S	.348
*9	24	.177	29	.136	16	.177	.2813	.1148	K	.281	.346	.097	S	.348
10	30	.190	22	.157	11	.191	.3026	.1234	N	.302	.372	.105	V	.372
*10	32	.190	21	.159	11	.191	.3026	.1234	N	.302	.372	.105	V	.372
*10	24	.190	25	.1495	11	.191	.3026	.1234	N	.302	.372	.105	V	.372
12	28	.216	14	.182	2	.221	.3452	.1405	S	.348	.424	.120	7/16	.437
*12	24	.216	16	.177	2	.221	.3452	.1405	S	.348	.424	.120	7/16	.437
14	24	.242	7	.201	C	.242	.3879	.1577	X	.397	.472	.135	31/64	.484
*14	20	.242	10	.1935	C	.242	.3879	.1577	X	.397	.472	.135	31/64	.484
16	22	.268	1	.228	I	.272	.4305	.1748	7/16	.437	.528	.150	17/32	.531
*16	20	.268	7/32	.2187	I	.272	.4305	.1748	7/16	.437	.528	.150	17/32	.531
18	20	.294	D	.246	M	.295	.4731	.1920	31/64	.484	.580	.164	19/32	.593
*18	18	.294	C	.242	M	.295	.4731	.1920	31/64	.484	.580	.164	19/32	.593
20	20	.320	I	.272	P	.323	.5158	.2092	33/64	.515	.632	.179	41/64	.640
*20	18	.320	H	.266	P	.323	.5158	.2092	33/64	.515	.632	.179	41/64	.640
22	18	.346	L	.290	S	.348	.5584	.2263	9/16	.562	.682	.194	11/16	.687
*22	16	.346	K	.281	S	.348	.5584	.2263	9/16	.562	.682	.194	11/16	.687
24	16	.372	5/16	.3125	V	.377	.6010	.2435	39/64	.609	.732	.209	47/64	.734
*24	18	.372	O	.316	V	.377	.6010	.2435	39/64	.609	.732	.209	47/64	.734
26	16	.398	R	.339	Y	.404	.6437	.2606	21/32	.656	.788	.224	51/64	.796
*26	14	.398	21/64	.3281	Y	.404	.6437	.2606	21/32	.656	.788	.224	51/64	.796
28	14	.424	T	.358	7/16	.437	.6863	.2178	11/16	.687	.840	.239	27/32	.843
*28	16	.424	U	.368	7/16	.437	.6863	.2178	11/16	.687	.840	.239	27/32	.843
30	14	.450	V	.377	29/64	.453	.7270	.2950	47/64	.734	.892	.254	29/32	.906
*30	16	.450	25/64	.386	29/64	.453	.7270	.2950	47/64	.734	.892	.254	29/32	.906

* Special sizes of A. S. M. E. machine screws.

The National Screw Thread Commission recommends that the numbered series stop with the No. 12 size and that larger machine screws be made in fractional sizes. The drill sizes given allow for a tapped hole with $\frac{3}{4}$ depth of thread.

Head Dimensions Flat-head Machine Screws



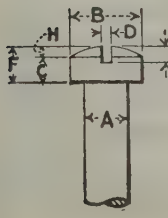
Dimensions	FORMULA	
	Maximum	Minimum
B	2.04A − 0.003	1.96A − 0.013
C	0.619A − 0.002	0.552A − 0.007
D	0.182A + 0.020	0.164A + 0.010
E	0.228A − 0.002	0.192A − 0.002
W	82°	80°

	A	*B*		*C*		*D*		*E*	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	0.073	0.146	0.130	0.043	0.033	0.033	0.022	0.019	0.012
2	0.086	0.172	0.156	0.051	0.040	0.036	0.024	0.023	0.015
3	0.099	0.199	0.181	0.059	0.048	0.038	0.026	0.027	0.017
4	0.112	0.225	0.207	0.067	0.055	0.040	0.028	0.030	0.020
5	0.125	0.252	0.232	0.075	0.062	0.043	0.031	0.034	0.022
6	0.138	0.279	0.257	0.083	0.069	0.045	0.033	0.038	0.024
8	0.164	0.332	0.308	0.100	0.084	0.050	0.037	0.045	0.029
10	0.190	0.385	0.359	0.116	0.098	0.055	0.041	0.053	0.034
12	0.216	0.438	0.410	0.132	0.112	0.059	0.045	0.060	0.039
¼	0.250	0.507	0.477	0.153	0.131	0.066	0.051	0.070	0.046
5/16	0.313	0.636	0.600	0.192	0.166	0.077	0.061	0.088	0.058
⅜	0.375	0.762	0.722	0.230	0.200	0.088	0.072	0.106	0.070
7/16	0.438	0.891	0.845	0.269	0.235	0.100	0.082	0.124	0.082
½	0.500	1.017	0.967	0.308	0.269	0.111	0.092	0.142	0.094

A dimensions are maximum for body diameter and are used for formulae calculations. These dimensions are identical to maximum major thread diameters.

The minimum for *A* is the minimum major thread diameter.

Head Dimensions Fillister-head Machine Screws



Dimensions	FORMULA	
	Maximum	Minimum
B	1.67A − 0.004	1.61A − 0.014
C	0.66A − 0.002	0.60A − 0.007
D	0.182A + 0.020	0.164A + 0.001
E	0.44A − 0.001	0.374A − 0.011
F	0.88A − 0.003	0.82A − 0.008
H	0.28A + 0.004	0.22A − 0.001

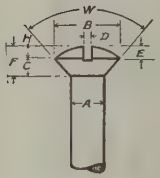
Head Dimensions of Fillister-head Machine Screws

	A	*B*		*C*		*D*		*E*		*F*		*H*	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	0.073	0.118	0.104	0.046	0.037	0.033	0.022	0.031	0.016	0.061	0.052	0.024	0.015
2	0.086	0.140	0.124	0.055	0.045	0.036	0.024	0.037	0.021	0.073	0.063	0.028	0.018
3	0.099	0.161	0.145	0.063	0.052	0.038	0.026	0.043	0.026	0.084	0.073	0.032	0.021
4	0.112	0.183	0.166	0.072	0.060	0.040	0.028	0.048	0.031	0.096	0.084	0.035	0.024
5	0.125	0.205	0.187	0.081	0.068	0.043	0.031	0.054	0.036	0.107	0.095	0.039	0.027
6	0.138	0.226	0.208	0.089	0.076	0.045	0.033	0.060	0.041	0.118	0.105	0.043	0.029
8	0.164	0.270	0.250	0.106	0.091	0.050	0.037	0.071	0.050	0.141	0.126	0.050	0.035
10	0.190	0.313	0.292	0.123	0.107	0.055	0.041	0.083	0.060	0.164	0.148	0.057	0.041
12	0.216	0.357	0.334	0.141	0.123	0.059	0.045	0.094	0.070	0.187	0.169	0.064	0.047
$\frac{1}{4}$	0.250	0.414	0.389	0.163	0.143	0.066	0.051	0.109	0.083	0.217	0.197	0.074	0.054
$\frac{5}{16}$	0.313	0.519	0.490	0.205	0.181	0.077	0.061	0.137	0.106	0.272	0.249	0.092	0.068
$\frac{3}{8}$	0.375	0.622	0.590	0.246	0.218	0.088	0.072	0.164	0.129	0.327	0.300	0.109	0.082
$\frac{7}{16}$	0.438	0.727	0.691	0.287	0.256	0.100	0.082	0.192	0.153	0.382	0.351	0.127	0.095
$\frac{1}{2}$	0.500	0.831	0.791	0.328	0.293	0.111	0.092	0.219	0.176	0.437	0.402	0.144	0.109

A dimensions are maximum for body diameter and are used for formulae calculations. These dimensions are identical to maximum major thread diameters.

The minimum for *A* is the minimum major thread diameter.

Head Dimensions Oval-head Machine Screws



Dimensions	FORMULA	
	Maximum	Minimum
B	2.04A − 0.003	1.96A − 0.013
C	0.619A − 0.002	0.552A − 0.007
D	0.182A + 0.020	0.164A + 0.010
E	0.556A − 0.003	0.460A − 0.003
F	0.923A + 0.001	0.820A − 0.008
H	0.304A + 0.003	0.268A − 0.001
W	82°	80°

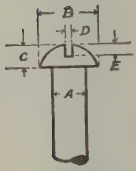
Head Dimension Oval-head Machine Screws

	A	B		C		D		E		F		H	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	0.073	0.146	0.130	0.043	0.033	0.033	0.022	0.038	0.031	0.068	0.052	0.025	0.019
2	0.086	0.172	0.156	0.051	0.040	0.036	0.024	0.045	0.037	0.080	0.063	0.029	0.022
3	0.099	0.199	0.181	0.059	0.048	0.038	0.026	0.052	0.043	0.092	0.073	0.033	0.026
4	0.112	0.225	0.207	0.067	0.055	0.040	0.028	0.059	0.049	0.104	0.084	0.037	0.029
5	0.125	0.252	0.232	0.075	0.062	0.043	0.031	0.067	0.055	0.116	0.095	0.041	0.033
6	0.138	0.279	0.257	0.083	0.069	0.045	0.033	0.074	0.060	0.128	0.105	0.045	0.036
8	0.164	0.332	0.308	0.100	0.084	0.050	0.037	0.088	0.072	0.152	0.126	0.053	0.043
10	0.190	0.385	0.359	0.116	0.098	0.055	0.041	0.103	0.084	0.176	0.148	0.061	0.050
12	0.216	0.438	0.410	0.132	0.112	0.059	0.045	0.117	0.096	0.200	0.169	0.069	0.057
1/4	0.250	0.507	0.477	0.153	0.131	0.066	0.051	0.136	0.112	0.232	0.197	0.079	0.066
5/16	0.313	0.636	0.600	0.192	0.166	0.077	0.061	0.171	0.141	0.290	0.249	0.098	0.083
3/8	0.375	0.762	0.722	0.230	0.200	0.088	0.072	0.206	0.170	0.347	0.300	0.117	0.100
7/16	0.438	0.891	0.845	0.269	0.235	0.100	0.082	0.241	0.198	0.405	0.351	0.136	0.116
1/2	0.500	1.017	0.967	0.308	0.269	0.111	0.092	0.275	0.227	0.463	0.402	0.155	0.133

A dimensions are maximum for body diameter and are used for formulae calculations. These dimensions are identical to maximum major thread diameters.

The minimum for *A* is the minimum major thread diameter. (Pheoll Mfg. Co.)

Head Dimensions Round-head Machine Screws



Dimensions	FORMULA	
	Maximum	Minimum
B	1.887A	1.813A − 0.010
C	0.636A + 0.015	0.624A + 0.005
D	0.182A + 0.020	0.164A + 0.010
E	0.362A + 0.017	0.268A + 0.013

	A	*B*		*C*		*D*		*E*	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	0.073	0.138	0.122	0.061	0.051	0.033	0.022	0.043	0.033
2	0.086	0.162	0.146	0.070	0.059	0.036	0.024	0.048	0.036
3	0.099	0.187	0.169	0.078	0.067	0.038	0.026	0.053	0.040
4	0.112	0.211	0.193	0.086	0.075	0.040	0.028	0.058	0.043
5	0.125	0.236	0.217	0.095	0.083	0.043	0.031	0.062	0.047
6	0.138	0.260	0.240	0.103	0.091	0.045	0.033	0.067	0.050
8	0.164	0.309	0.287	0.119	0.107	0.050	0.037	0.076	0.057
10	0.190	0.359	0.334	0.136	0.124	0.055	0.041	0.086	0.064
12	0.216	0.408	0.382	0.152	0.140	0.059	0.045	0.095	0.071
$\frac{1}{4}$	0.250	0.472	0.443	0.174	0.161	0.066	0.051	0.108	0.080
$\frac{5}{16}$	0.313	0.591	0.557	0.214	0.200	0.077	0.061	0.130	0.097
$\frac{3}{8}$	0.375	0.708	0.670	0.254	0.239	0.088	0.072	0.153	0.114
$\frac{7}{16}$	0.438	0.827	0.784	0.294	0.278	0.100	0.082	0.176	0.130
$\frac{1}{2}$	0.500	0.944	0.897	0.333	0.317	0.111	0.092	0.198	0.147

A dimensions are maximum for body diameter and are used for formulae calculations. These dimensions are identical to maximum major thread diameters.

The minimum for *A* is the minimum major thread diameter.

STANDARD SIZES OF WRENCH HEAD BOLTS AND NUTS AND WRENCH OPENINGS

Proposed by the A. E. S. C., A. S. M. E. and S. A. E., October, 1925.

These standards are intended for general use by all industries to replace the various existing standards now in use.

These tables are believed to be acceptable to various industries and will cause little disturbance of present practice. Wherever possible, the U. S. standard sizes of bolt heads and nuts have been reduced to some existing shop standard after giving consideration to theoretical analysis of stresses in bolts and nuts and making tests of samples. Deviations from theoretical sizes have been made in order to keep the number of wrench openings small and to conform to manufacturing processes. The greatest possible tolerances have been allowed, but will usually be much less in practice.

The number of wrench openings required have been reduced through simplification of outside dimensions of bolt heads and nuts and elimination of sizes little used. This has caused deviations from results calculated by formulas for sizes of bolt heads and nuts due to eliminating the thirty-seconds from all sizes.

The sizes of bolt heads and nuts are intended to supersede all existing standards which have grown up for commercial standard bolt heads and nuts.

It will be noted that the maximum sizes of both finished and rough products are the same, so that wrenches are applicable interchangeably to either class of bolt head or nut. In all cases the *nominal* or *basic* widths across flats of bolt heads and nuts have been taken as *maximum* sizes, and the tolerances on bolt heads and nuts are minus only.

The *minimum* wrench openings provide a positive *clearance* between maximum nut and minimum wrench and the tolerances on *wrench openings* are *plus* only. This insures a fit of the wrench to the bolt head and nut. The tolerance allowed the wrench manufacturer has been made as great as is possible without causing the deformation of the corners of bolt heads or nuts.

TABLE 1.—ROUGH AND SEMI-FINISHED SQUARE AND HEXAGONAL REGULAR BOLT HEADS

(All Dimensions in Inches. D = Diameter of Bolts)

Diameter of Bolt D	Width across Flats			Minimum Width across Corners		Height		
	Maximum		Minimum	Hex.	Square	Nominal	Maximum	Minimum
$\frac{1}{4}$ 0.2500	$\frac{3}{8}$	0.3750	0.363	0.414	0.498	$\frac{11}{64}$	0.188	0.156
$\frac{5}{16}$ 0.3125	$\frac{1}{2}$	0.5000	0.484	0.552	0.665	$\frac{13}{64}$	0.220	0.186
$\frac{3}{8}$ 0.3750	$\frac{9}{16}$	0.5625	0.544	0.620	0.747	$\frac{1}{4}$	0.268	0.232
$\frac{7}{16}$ 0.4375	$\frac{5}{8}$	0.6250	0.603	0.687	0.828	$\frac{19}{64}$	0.316	0.278
$\frac{1}{2}$ 0.5000	$\frac{3}{4}$	0.7500	0.725	0.827	0.995	$\frac{21}{64}$	0.348	0.308
$\frac{9}{16}$ 0.5625	$\frac{7}{8}$	0.8750	0.847	0.966	1.163	$\frac{3}{8}$	0.396	0.354
$\frac{5}{8}$ 0.6250	$1\frac{1}{16}$	0.9375	0.906	1.033	1.244	$\frac{27}{64}$	0.444	0.400
$\frac{3}{4}$ 0.7500	$1\frac{1}{8}$	1.1250	1.088	1.240	1.494	$\frac{1}{2}$	0.524	0.476
$\frac{7}{8}$ 0.8750	$1\frac{5}{16}$	1.3125	1.269	1.447	1.742	$\frac{19}{32}$	0.620	0.568
1 1.0000	$1\frac{1}{2}$	1.5000	1.450	1.653	1.991	$\frac{21}{32}$	0.684	0.628
$1\frac{1}{8}$ 1.1250	$1\frac{11}{16}$	1.6875	1.631	1.859	2.239	$\frac{3}{4}$	0.780	0.720
$1\frac{1}{4}$ 1.2500	$1\frac{7}{8}$	1.8750	1.813	2.067	2.489	$\frac{27}{32}$	0.876	0.812
$1\frac{3}{8}$ 1.5000	$2\frac{1}{16}$	2.2500	2.175	2.480	2.986	1	1.036	0.964
$1\frac{3}{4}$ 1.7500	$2\frac{1}{8}$	2.6250	2.538	2.893	3.485	$1\frac{5}{32}$	1.196	1.116
2 2.0000	3	3.0000	2.900	3.306	3.982	$1\frac{11}{32}$	1.388	1.300
$2\frac{1}{4}$ 2.2500	$3\frac{3}{8}$	3.3750	3.263	3.720	4.480	$1\frac{1}{2}$	1.548	1.452
$2\frac{1}{2}$ 2.5000	$3\frac{3}{4}$	3.7500	3.625	4.133	4.977	$1\frac{21}{32}$	1.708	1.604
$2\frac{3}{4}$ 2.7500	$4\frac{1}{8}$	4.1250	3.988	4.546	5.476	$1\frac{27}{32}$	1.885	1.773
3 3.0000	$4\frac{1}{2}$	4.5000	4.350	4.959	5.973	2	2.060	1.960

Formulas

Width across flats of rough and semi-finished regular bolt heads shall be $1\frac{1}{2}$ D with adjustments in the $\frac{1}{16}$-inch sizes to eliminate $\frac{1}{32}$-inch size wrench openings.

Tolerance for width across flats shall be minus 0.05 D.

Minimum width across rounded corners of hexagon equals 1.14 times minimum width across flats.

Height of head shall be $\frac{2}{3}$ D.

Tolerance for height of head for rough bolts shall be 0.032 D + 0.024.

The top of bolt head shall be flat and chamfered, angle of chamfer with top surface 30 degrees; diameter of top flat circle shall be 100 per cent of the nominal width across flats.

Tolerance on top flat circle shall be minus 15 per cent.

Rough and semi-finished regular bolt heads shall be at right angles to the body within 3 degrees and concentric with the body within a tolerance of 3 per cent of the distance across flats.

Width across flats shall be measured at the bottom of the bolt head. Taper of sides of bolt heads shall not exceed 4 degrees.

Minimum width across rounded corners of square equals 1.373 times minimum width across flats.

TABLE 2.—FINISHED SQUARE AND HEXAGONAL BOLT HEADS
(All Dimensions in Inches. D = Diameter of Bolts)

Diameter of Bolt D		Bolt Head							
		Width across Flats			Minimum Width across Corners		Height		
		Maximum		Minimum	Hex.	Square	Nominal	Maximum	Minimum
$\frac{1}{4}$	0.2500	$\frac{7}{16}$	0.4375	0.428	0.488	0.588	$\frac{3}{16}$	0.194	0.180
$\frac{5}{16}$	0.3125	$\frac{1}{2}$	0.5625	0.552	0.628	0.757	$\frac{13}{64}$	0.242	0.227
$\frac{3}{8}$	0.3750	$\frac{9}{16}$	0.6250	0.613	0.699	0.840	$\frac{7}{32}$	0.289	0.273
$\frac{7}{16}$	0.4375	$\frac{3}{4}$	0.7500	0.737	1.840	1.012	$\frac{21}{64}$	0.337	0.319
$\frac{1}{2}$	0.5000	$\frac{13}{16}$	0.8125	0.799	0.911	1.096	$\frac{3}{8}$	0.385	0.365
$\frac{9}{16}$	0.5625	$\frac{7}{8}$	0.8750	0.860	0.980	1.181	$\frac{27}{64}$	0.433	0.411
$\frac{5}{8}$	0.6250	$\frac{15}{16}$	0.9375	0.922	1.052	1.266	$\frac{15}{32}$	0.481	0.457
$\frac{3}{4}$	0.7500	1 $\frac{1}{8}$	1.1250	1.107	1.263	1.519	$\frac{9}{16}$	0.576	0.549
$\frac{7}{8}$	0.8750	1 $\frac{5}{16}$	1.3125	1.293	1.474	1.775	$\frac{21}{32}$	0.672	0.641
1	1.0000	1 $\frac{1}{2}$	1.5000	1.479	1.686	2.031	$\frac{3}{4}$	0.768	0.733
1 $\frac{1}{8}$	1.1250	1 $\frac{11}{16}$	1.6875	1.665	1.898	2.286	$\frac{27}{32}$	0.863	0.824
1 $\frac{1}{4}$	1.2500	1 $\frac{7}{8}$	1.8750	1.850	2.109	2.540	$\frac{15}{16}$	0.959	0.916
1 $\frac{3}{8}$	1.5000	2 $\frac{1}{4}$	2.2500	2.222	2.534	3.051	1 $\frac{1}{8}$	1.150	1.100
1 $\frac{1}{2}$	1.7500	2 $\frac{5}{8}$	2.6250	2.593	2.955	3.560	1 $\frac{5}{16}$	1.341	1.284
2	2.0000	3	3.0000	2.964	3.379	4.070	1 $\frac{1}{2}$	1.533	1.468
2 $\frac{1}{4}$	2.2500	3 $\frac{3}{8}$	3.3750	3.335	3.802	4.579	1 $\frac{11}{16}$	1.724	1.651
2 $\frac{1}{2}$	2.5000	3 $\frac{3}{4}$	3.7500	3.707	4.226	5.090	1 $\frac{7}{8}$	1.915	1.835
2 $\frac{3}{4}$	2.7500	4 $\frac{1}{8}$	4.1250	4.078	4.646	5.599	2 $\frac{1}{16}$	2.106	2.019
3	3.0000	4 $\frac{1}{2}$	4.5000	4.449	5.072	6.108	2 $\frac{1}{4}$	2.298	2.203

Formulas

Width across flats of finished hexagonal bolt heads shall be $1\frac{1}{2}\ D$ except that on bolts from $\frac{1}{4}$ to $\frac{5}{16}$ inch in diameter the width across flats $= 1\frac{1}{2}\ D + \frac{1}{16}$ inch with adjustments in the $\frac{1}{16}$-inch sizes, to eliminate $\frac{1}{32}$-inch-size wrenchopenings.

Tolerance for width across flats shall be minus $0.015\ D + 0.006$.

Height of heads from top of head to under side of washer face shall be $\frac{1}{4}\ D$.

Tolerance for heights of heads shall be $0.030\ D + 0.005$.

Minimum width across rounded corners of hexagon equals 1.14 times minimum width across flats.

The finished top shall be flat and chamfered; angle of chamfer with top surface 30 degrees; diameter of top flat circle shall be 100 per cent of the nominal width across flats.

Tolerance on top flat circle shall be minus 15 per cent.

Finished bolt heads shall be at right angles to the body within 2 degrees and concentric with the body within a tolerance of 3 per cent of the distance across the flats.

All finished bolts shall be washer faced, the thickness of the washer face parts shall be the distance from top of head to bearing surface.

The thickness of washer face shall be $\frac{1}{64}$ inch.

The bearing surface of washer face shall equal the width across flats with a plus or minus tolerance of 5 per cent.

Minimum width across rounded corners of square equals 1.373 times minimum width across flats.

TABLE 3.—FINISHED HEXAGONAL CAP SCREW HEADS
(All Dimensions in Inches. D = Diameter of Bolts)

Diameter of Screw D	Width across Flats		Minimum Width across Corners	Height		
	Maximum	Minimum		Nominal	Maximum	Minimum
$\frac{1}{4}$ 0.2500	$\frac{7}{16}$ 0.4375	0.428	0.488	$\frac{3}{16}$	0.194	0.181
$\frac{5}{16}$ 0.3125	$\frac{1}{2}$ 0.5000	0.489	0.558	$\frac{15}{64}$	0.242	0.227
$\frac{3}{8}$ 0.3750	$\frac{9}{16}$ 0.5625	0.551	0.628	$\frac{9}{32}$	0.289	0.274
$\frac{7}{16}$ 0.4375	$\frac{5}{8}$ 0.6250	0.612	0.699	$\frac{21}{64}$	0.337	0.319
$\frac{1}{2}$ 0.5000	$\frac{3}{4}$ 0.7500	0.737	0.840	$\frac{3}{8}$	0.385	0.365
$\frac{9}{16}$ 0.5625	$\frac{13}{16}$ 0.8125	0.798	0.910	$\frac{27}{64}$	0.433	0.411
$\frac{5}{8}$ 0.6250	$\frac{7}{8}$ 0.8750	0.860	0.980	$\frac{15}{32}$	0.481	0.457
$\frac{3}{4}$ 0.7500	1 1.0000	0.983	1.120	$\frac{1}{2}$	0.576	0.549
$\frac{7}{8}$ 0.8750	$1\frac{1}{8}$ 1.1250	1.106	1.261	$\frac{21}{32}$	0.672	0.641
1 1.0000	$1\frac{1}{16}$ 1.3125	1.291	1.474	$\frac{3}{4}$	0.768	0.733
$1\frac{1}{8}$ 1.1250	$1\frac{1}{2}$ 1.5000	1.477	1.686	$\frac{27}{32}$	0.863	0.824
$1\frac{1}{4}$ 1.2500	$1\frac{11}{16}$ 1.6875	1.663	1.898	$\frac{15}{16}$	0.959	0.916

Formulas

Width across flats of cap screw heads shall be as follows:

Diameter of Bolt	Width across Flats
$\frac{1}{4}$ to $\frac{7}{16}$	$D + \frac{3}{16}$
$\frac{1}{2}$ to $\frac{7}{8}$	$D +$
1	$D + \frac{5}{16}$
$1\frac{1}{8}$	$D + \frac{3}{8}$
$1\frac{1}{4}$	$D + \frac{7}{16}$

Tolerance for width across flats shall be minus 0.015 D plus 0.006.

Height of heads shall be $\frac{2}{3}$ D.

Tolerance for height of heads shall be 0.030 D + 0.005.

Minimum width across rounded corners of hexagon equals 1.14 times minimum width across flats.

The finished top shall be flat and chamfered, angle of chamfer with top surface 30 degrees, diameter of top flat circle shall be 100 per cent of the nominal width across flats.

Tolerance in diameter of top flat circle shall be minus 15 per cent.

Cap screw heads shall be at right angles to the body within 2 degrees and concentric with the body within a tolerance of 3 per cent of the distance across the flats.

All cap screws shall be washer faced. The thickness of the washer-faced parts shall be the distance from top of head to bearing surface. The thickness of washer face shall be $\frac{1}{64}$ inch. The bearing surface of washer face shall be 100 per cent of the nominal width across flats.

Tolerance in diameter of circle of washer face shall be plus or minus 5 per cent.

Minimum width across rounded corners of square equals 1.373 times minimum width across flats.

TABLE 4.—SET SCREW HEADS
(All Dimensions in Inches. D = Diameter of Bolts)

Diameter of Screw D	Width across Flats		Height		
	Maximum	Minimum	Nominal	Maximum	Minimum
$\frac{1}{4}$ 0.2500	$\frac{1}{4}$ 0.2500	0.241	$\frac{3}{16}$	0.197	0.179
$\frac{5}{16}$ 0.3125	$\frac{5}{16}$ 0.3125	0.302	$\frac{15}{64}$	0.245	0.224
$\frac{3}{8}$ 0.3750	$\frac{3}{8}$ 0.3750	0.362	$\frac{9}{32}$	0.293	0.270
$\frac{7}{16}$ 0.4375	$\frac{7}{16}$ 0.4375	0.423	$\frac{21}{64}$	0.341	0.315
$\frac{1}{2}$ 0.5000	$\frac{1}{2}$ 0.5000	0.484	$\frac{3}{8}$	0.389	0.361
$\frac{9}{16}$ 0.5625	$\frac{9}{16}$ 0.5625	0.545	$\frac{27}{64}$	0.437	0.407
$\frac{5}{8}$ 0.6250	$\frac{5}{8}$ 0.6250	0.607	$\frac{15}{32}$	0.485	0.452
$\frac{3}{4}$ 0.7500	$\frac{3}{4}$ 0.7500	0.729	$\frac{9}{16}$	0.582	0.544
$\frac{7}{8}$ 0.8750	$\frac{7}{8}$ 0.8750	0.852	$\frac{21}{32}$	0.678	0.635
1 1.0000	1 1.0000	0.974	$\frac{3}{4}$	0.774	0.726
$1\frac{1}{8}$ 1.1250	$1\frac{1}{8}$ 1.1250	1.097	$\frac{27}{32}$	0.870	0.817
$1\frac{1}{4}$ 1.2500	$1\frac{1}{4}$ 1.2500	1.219	$\frac{15}{16}$	0.967	0.909
$1\frac{1}{2}$ 1.5000	$1\frac{1}{2}$ 1.5000	1.464	$1\frac{1}{8}$	1.159	1.091

Formulas

Width across flats of set screw heads shall be equal to diameter of screw (D).

Tolerance for width across flats shall be minus $0.020\ D + 0.006$ (except for $\frac{1}{4}$ and $\frac{5}{16}$).

Height of set screw heads shall be $\frac{3}{4}\ D$.

Tolerance for height of heads shall be $0.040\ D + 0.008$.

Width of neck under head to be not over 2 times the pitch of the thread.

The radius of the crown of the head is to be $2\frac{1}{2}\ D$.

When head is not necked, it must be beveled not more than 40 degrees under the head.

Minimum width across rounded corners of square equals 1.373 times minimum width across flats.

TABLE 5.—ROUGH AND SEMI-FINISHED SQUARE AND HEXAGONAL REGULAR NUTS

(All Dimensions in Inches. D = Diameter of Bolts)

Diameter of Bolt D		Width across Flats			Minimum Width across Corners		Thickness		
		Maximum		Minimum	Hex.	Square	Nominal	Maximum	Minimum
1/4	0.2500	7/16	0.4375	0.425	0.485	0.584	7/32	0.235	0.203
5/16	0.3125	1/2	0.5625	0.547	0.624	0.751	17/64	0.283	0.249
3/8	0.3750	9/16	0.6250	0.606	0.691	0.832	21/64	0.346	0.310
7/16	0.4375	3/4	0.7500	0.728	0.830	1.000	3/8	0.394	0.356
1/2	0.5000	13/16	0.8125	0.788	0.898	1.082	7/16	0.458	0.418
9/16	0.5625	7/8	0.8750	0.847	0.966	1.163	31/64	0.505	0.463
5/8	0.6250	15/16	0.9375	0.906	1.033	1.244	7/16	0.569	0.525
3/4	0.7500	1 1/8	1.1250	1.088	1.240	1.494	43/64	0.680	0.632
7/8	0.8750	1 5/16	1.3125	1.269	1.447	1.742	25/32	0.792	0.740
1	1.0000	1 1/2	1.5000	1.450	1.653	1.991	7/8	0.903	0.847
1 1/8	1.1250	1 11/16	1.6875	1.631	1.859	2.239	1	1.030	0.970
1 1/4	1.2500	1 7/8	1.8750	1.813	2.067	2.489	1 9/32	1.126	1.062
1 3/8	1.5000	2 1/4	2.2500	2.175	2.480	2.986	1 15/64	1.349	1.277
1 3/4	1.7500	2 5/8	2.6250	2.538	2.893	3.485	1 11/32	1.571	1.491
2	2.0000	3	3.0000	2.900	3.306	3.982	1 3/4	1.794	1.706
2 1/4	2.2500	3 3/8	3.3750	3.263	3.720	4.480	1 31/32	2.017	1.921
2 1/2	2.5000	3 3/4	3.7500	3.625	4.133	4.977	2 7/64	2.240	2.136
2 3/4	2.7500	4 1/8	4.1250	3.988	4.546	5.476	2 13/32	2.350	2.462
3	3.0000	4 1/2	4.5000	4.350	4.959	5.973	2 1/8	2.685	2.565

Formulas

Width across flats of rough and semi-finished regular nuts shall be $1\frac{1}{2}\ D$, except as follows: diameter of bolts $\frac{1}{4}$ to $\frac{1}{16}$ inch; width across flats = $1\frac{1}{2}\ D + \frac{1}{16}$ inch, with adjustment in the $\frac{1}{16}$-inch sizes to eliminate 32nd-inch-size wrench openings.

Tolerance for width across flats shall be minus 0.05 D.

Minimum width across rounded corners of hexagon equals 1.14 times minimum width across flats.

Thickness for rough and semi-finished nuts shall be $\frac{7}{8}\ D$.

Tolerance for thickness shall be $0.032\ D + 0.024$.

The top of rough and semi-finished regular square and hexagonal nuts shall be flat and chamfered; angle of chamfer with surface 30 degrees; diameter of top or both top and bottom circle shall be 100 per cent of the nominal width across flats.

Tolerance on top flat surface shall be minus 15 per cent.

Semi-finished nuts shall be faced on bearing surface and at right angles to the axis of the thread within 3 degrees.

Width across flats to be measured at the top of the nut.

Taper of sides of nuts not to exceed 4 degrees.

Minimum width across corners of square equals 1.373 times minimum width across flats.

TABLE 6.—FINISHED SQUARE AND HEXAGONAL REGULAR NUTS
(All Dimensions in Inches. D = Diameter of Bolt)

Diameter of Bolt D	Width across Flats		Minimum Width across Corners		Thickness		
	Maximum	Minimum	Hexagon	Square	Nominal	Maximum	Minimum
$\frac{1}{4}$ 0.2500	$\frac{7}{16}$ 0.4375	0.428	0.488	0.588	$\frac{7}{32}$	0.225	0.212
$\frac{5}{16}$ 0.3125	$\frac{9}{16}$ 0.5625	0.552	0.628	0.757	$\frac{17}{64}$	0.273	0.258
$\frac{3}{8}$ 0.3750	$\frac{5}{8}$ 0.6250	0.613	0.698	0.840	$\frac{21}{64}$	0.336	0.320
$\frac{7}{16}$ 0.4375	$\frac{3}{4}$ 0.7500	0.737	0.840	1.012	$\frac{3}{8}$	0.384	0.366
$\frac{1}{2}$ 0.5000	$\frac{13}{16}$ 0.8125	0.799	0.911	1.096	$\frac{7}{16}$	0.448	0.428
$\frac{9}{16}$ 0.5625	$\frac{7}{8}$ 0.8750	0.860	0.980	1.181	$\frac{31}{64}$	0.495	0.473
$\frac{5}{8}$ 0.6250	$\frac{15}{16}$ 0.9375	0.922	1.051	1.266	$\frac{35}{64}$	0.559	0.535
$\frac{3}{4}$ 0.7500	1 1.1250	1.108	1.263	1.517	$\frac{21}{32}$	0.670	0.642
$\frac{7}{8}$ 0.8750	$1\frac{1}{16}$ 1.3125	1.293	1.474	1.775	$\frac{49}{64}$	0.781	0.750
1 1.0000	$1\frac{1}{8}$ 1.5000	1.479	1.686	2.031	$\frac{7}{8}$	0.893	0.858
$1\frac{1}{8}$ 1.1250	$1\frac{13}{16}$ 1.6875	1.665	1.898	2.286	1	1.019	0.981
$1\frac{1}{4}$ 1.2500	$1\frac{7}{8}$ 1.8750	1.850	2.109	2.540	$1\frac{3}{32}$	1.115	1.072
$1\frac{3}{8}$ 1.5000	$2\frac{1}{4}$ 2.2500	2.222	2.533	3.051	$1\frac{5}{16}$	1.338	1.288
$1\frac{1}{2}$ 1.7500	$2\frac{5}{8}$ 2.6250	2.593	2.956	3.560	$1\frac{17}{32}$	1.560	1.503
2 2.0000	3 3.0000	2.964	3.379	4.070	$1\frac{3}{4}$	1.783	1.718
$2\frac{1}{4}$ 2.2500	$3\frac{3}{8}$ 3.3750	3.335	3.802	4.579	$1\frac{49}{64}$	2.005	1.932
$2\frac{1}{2}$ 2.5000	$3\frac{3}{4}$ 3.7500	3.707	4.226	5.090	$2\frac{3}{16}$	2.228	2.148
$2\frac{3}{4}$ 2.7500	$4\frac{1}{8}$ 4.1250	4.078	4.646	5.599	$2\frac{13}{32}$	2.450	2.363
3 3.0000	$4\frac{1}{2}$ 4.5000	4.449	5.072	6.108	$2\frac{5}{8}$	2.673	2.578

Formulas

Width across flats of finished hexagonal and square regular nuts shall be $1\frac{1}{2}$ D except as follows: $\frac{1}{4}$ to $\frac{9}{16}$ inch = $1\frac{1}{2}$ D + $\frac{1}{16}$ inch with adjustment in the 16th-inch sizes to eliminate 32nd-inch-size wrench openings.

Tolerance for width across flats shall be minus 0.015 D + 0.006.

Minimum width across corners of hexagon equals 1.14 times minimum width across flats.

Thickness of finished regular nuts shall be $\frac{7}{8}$ D.

Tolerance for thickness shall be 0.030 D + 0.005.

The finished top of finished nuts shall be flat and chamfered; angle of chamfer with surface 30 degrees; diameter of top, or both top and bottom circle, shall be 100 per cent of the nominal width across flats.

Tolerance on top flat surface shall be minus 15 per cent.

All finished hexagon and square regular nuts shall be washer faced; the thickness of the washer face shall be $\frac{1}{64}$ inch. The bearing surface of the washer face shall be 100 per cent of the nominal width across flats. Tolerance on the diameter of the washer face shall be plus or minus 5 per cent.

The axis of the threaded hole shall be at right angles to the washer face within a tolerance of 2 degrees.

Minimum width across rounded corners of square equals 1.373 times minimum width across flats.

TABLE 7.—FINISHED AND SEMI-FINISHED JAM NUTS
(All Dimensions in Inches. D = Diameter of Bolts)

Diameter of Bolt D		Width across Flats			Width across Corners of Hexagon	Thickness		
		Maximum		Minimum	Minimum	Nominal	Maximum	Minimum
$\frac{1}{4}$	0.2500	$\frac{7}{16}$	0.4375	0.428	0.488	$\frac{5}{32}$	0.163	0.150
$\frac{5}{16}$	0.3125	$\frac{9}{16}$	0.5625	0.552	0.628	$\frac{3}{16}$	0.195	0.180
$\frac{3}{8}$	0.3750	$\frac{5}{8}$	0.6250	0.613	0.699	$\frac{7}{32}$	0.227	0.211
$\frac{7}{16}$	0.4375	$\frac{3}{4}$	0.7500	0.737	0.840	$\frac{1}{4}$	0.259	0.241
$\frac{1}{2}$	0.5000	$\frac{13}{16}$	0.8125	0.799	0.911	$\frac{5}{16}$	0.323	0.303
$\frac{9}{16}$	0.5625	$\frac{7}{8}$	0.8750	0.860	0.980	$\frac{11}{32}$	0.355	0.333
$\frac{5}{8}$	0.6250	$\frac{15}{16}$	0.9375	0.922	1.051	$\frac{3}{8}$	0.387	0.363
$\frac{3}{4}$	0.7500	$1\frac{1}{8}$	1.1250	1.108	1.263	$\frac{7}{16}$	0.451	0.424
$\frac{7}{8}$	0.8750	$1\frac{5}{16}$	1.3125	1.293	1.474	$\frac{1}{2}$	0.516	0.484
1	1.0000	$1\frac{1}{2}$	1.5000	1.479	1.686	$\frac{9}{16}$	0.580	0.545
$1\frac{1}{8}$	1.1250	$1\frac{11}{16}$	1.6875	1.665	1.898	$\frac{5}{8}$	0.644	0.606
$1\frac{1}{4}$	1.2500	$1\frac{7}{8}$	1.8750	1.850	2.109	$\frac{11}{16}$	0.771	0.729
$1\frac{3}{8}$	1.5000	$2\frac{1}{4}$	2.2500	2.222	2.538	$\frac{3}{4}$	0.900	0.850
$1\frac{3}{4}$	1.7500	$2\frac{5}{8}$	2.6250	2.593	2.956	1	1.029	0.971
2	2.0000	3	3.0000	2.964	3.379	$1\frac{1}{8}$	1.158	1.093
$2\frac{1}{4}$	2.2500	$3\frac{3}{8}$	3.3750	3.335	3.802	$1\frac{1}{4}$	1.286	1.214
$2\frac{1}{2}$	2.5000	$3\frac{3}{4}$	3.7500	3.707	4.226	$1\frac{3}{8}$	1.540	1.460
$2\frac{3}{4}$	2.7500	$4\frac{1}{8}$	4.1250	4.078	4.649	$1\frac{5}{8}$	1.669	1.581
3	3.0000	$4\frac{1}{2}$	4.5000	4.449	5.072	$1\frac{3}{4}$	1.798	1.703

Formulas

Width across flats of Jam nuts shall be $1\frac{1}{2}\ D$ except as follows: diameter of bolts, $\frac{1}{4}$ to $\frac{5}{8}$ inch; width across flats, $1\frac{1}{2}\ D + \frac{1}{16}$ inch, with adjustments in the 16th-inch sizes to eliminate 32nd-inch-size wrench openings.

Tolerance for width across flats shall be minus $0.015\ D + 0.006$.

Minimum width across rounded corners of hexagon equals 1.14 times minimum width across flats.

Thickness of Jam nuts, sizes $\frac{1}{4}$ to $\frac{7}{16}$ inch, shall be $\frac{1}{2}\ D + \frac{1}{32}$; for sizes $\frac{1}{2}$ to $1\frac{1}{8}$ inches, $\frac{1}{2}\ D + \frac{1}{16}$; for sizes $1\frac{1}{4}$ to $2\frac{1}{4}$ inches, $\frac{1}{2}\ D + \frac{1}{8}$; $2\frac{1}{2}$ to 3 inches $\frac{1}{2}\ D + \frac{1}{4}$.

Tolerance for thickness shall be $0.030\ D + 0.005$.

The finished top or both top and bottom of Jam nuts shall be flat and chamfered; angle of chamfer with surface 30 degrees; diameter of top, or both top and bottom circles, shall be 100 per cent of the nominal width across flats.

Tolerance on top flat surface shall be minus 15 per cent.

For Jam nuts with a washer face, the thickness of the washer face shall be $\frac{1}{64}$ inch. The bearing surface of washer face shall be 100 per cent of the nominal width across flats.

Tolerance on the diameter of the washer face shall be plus or minus 5 per cent.

The axis of the threaded hole shall be at right angles to the washer face within a tolerance of 2 degrees.

Minimum width across rounded corners of square equals 1.373 times minimum width across flats.

Table 8.—Hexagon Light Nuts

(All Dimensions in Inches. D = Diameter of Bolts)

Note.—Light nuts are recommended for use with fine threads only.

Diameter of Bolt D	Width across Flats			Minimum Width across Corners		Thickness		
	Maximum		Minimum	Hex.	Square	Nominal	Maximum	Minimum
$\frac{1}{4}$ 0.2500	$\frac{7}{16}$	0.4375	0.428	0.488	0.588	$\frac{7}{32}$	0.225	0.212
$\frac{5}{16}$ 0.3125	$\frac{1}{2}$	0.5000	0.489	0.557	0.671	$\frac{17}{64}$	0.273	0.259
$\frac{3}{8}$ 0.3750	$\frac{9}{16}$	0.5625	0.551	0.628	0.757	$\frac{21}{64}$	0.336	0.320
$\frac{7}{16}$ 0.4375	$\frac{5}{8}$	0.6250	0.612	0.699	0.840	$\frac{3}{8}$	0.384	0.366
$\frac{1}{2}$ 0.5000	$\frac{3}{4}$	0.7500	0.737	0.840	1.012	$\frac{7}{16}$	0.448	0.428

Formulas

Thickness of light nuts shall be $\frac{7}{8}$ D (to nearest sixty-fourth lower for $\frac{1}{4}$ and $\frac{7}{16}$ sizes).

Tolerances for width across flats shall be minus $0.015\ D + 0.006$.

Tolerance for thickness shall be $0.030\ D + 0.005$.

The finished tops of the nuts, when not castellated, shall be flat and chamfered; angle of chamfer with top surface 30 degrees; diameter of top flat circle shall be 100 per cent of the nominal width across flats.

Tolerance on flat top circle shall be minus 15 per cent.

Nuts shall be washer faced. The thickness of the washer face shall be $\frac{1}{64}$ inch. The bearing surface of the washer face shall be 100 per cent of the nominal width across flats. Tolerance on diameter of washer face shall be plus or minus 5 per cent.

Minimum width across rounded corners of square equals 1.373 times minimum width across flats.

Table 9.—Hexagonal and Square Machine Screw Nuts and Stove-bolt Nuts

(All Dimensions in Inches. D = Diameter of Bolts)

Diameter of Screw D	Width across Flats		Width across Corners of Hexagon	Thickness		
	Maximum	Minimum	Minimum	Nominal	Maximum	Minimum
No. 0 0.0600	5/32 0.1562	0.150	0.171	3/64	0.050	0.043
No. 1 0.0730	5/32 0.1562	0.150	0.171	3/64	0.050	0.043
No. 2 0.0860	3/16 0.1875	0.180	0.205	1/16	0.066	0.057
No. 3 0.0990	3/16 0.1874	0.180	0.205	1/16	0.066	0.057
No. 4 0.1120	1/4 0.2500	0.241	0.275	3/32	0.098	0.087
No. 5 0.1250	5/16 0.3125	0.302	0.344	7/64	0.114	0.102
No. 6 0.1380	5/16 0.3125	0.302	0.344	7/64	0.114	0.102
No. 8 0.1640	11/32 0.3437	0.332	0.378	1/8	0.130	0.117
No. 10 0.1900	3/8 0.3750	0.362	0.413	1/8	0.130	0.117
No. 12 0.2160	7/16 0.4375	0.423	0.482	5/32	0.161	0.148
1/4 0.2500	7/16 0.4375	0.423	0.482	3/16	0.193	0.178
5/16 0.3125	9/16 0.5625	0.545	0.621	3/32	0.225	0.208
3/8 0.3750	5/8 0.6250	0.607	0.692	1/4	0.257	0.239
7/16 0.4375	3/4 0.7500	0.729	0.831	9/32	0.289	0.269
1/2 0.5000	13/16 0.8125	0.790	0.901	5/16	0.321	0.299

Formulas

Width across flats of machine screw and stove-bolt nuts shall be as follows: diameter of screw 1/4 to 1/2 inch; width across flats = $1\frac{1}{2}\ D + \frac{1}{16}$ inch, with adjustments in the 16th-inch sizes to eliminate 32nd-inch-size wrench openings.

Minimum width across rounded corners of square equals 1.373 times minimum width across flats.

TABLE 10.—OPEN-END WRENCH OPENINGS
(All Dimensions in Inches. D = Diameter of Bolts)

Basic Width across Flats, Bolt Heads and Nuts	Clearance	Tolerance	Dimensions of Measuring Blocks for Wrench Openings	
			Maximum	Minimum
5/32 0.1562	.0014	.005	0.163	0.158
3/16 0.1875	.0016	.005	0.194	0.189
1/4 0.2500	.0018	.005	0.257	0.252
5/16 0.3125	.0019	.007	0.321	0.314
11/32 0.3437	.0022	.007	0.353	0.346
3/8 0.3750	.0024	.007	0.384	0.377
7/16 0.4375	.0025	.007	0.447	0.440
1/2 0.5000	.0030	.007	0.510	0.503
9/16 0.5625	.0035	.007	0.573	0.566
5/8 0.6250	.0040	.007	0.636	0.629
3/4 0.7500	.0050	.008	0.763	0.755
13/16 0.8125	.0050	.008	0.826	0.818
7/8 0.8750	.0050	.008	0.888	0.880
15/16 0.9375	.0055	.009	0.952	0.943
1 1.0000	.0060	.009	1.015	1.006
1 1/8 1.1250	.0070	.010	1.142	1.132
1 1/4 1.2500	.0070	.010	1.267	1.257
1 5/16 1.3125	.0075	.011	1.331	1.320
1 1/2 1.5000	.0090	.012	1.521	1.509
1 11/16 1.6875	.0095	.013	1.710	1.697
1 7/8 1.8750	.0100	.013	1.898	1.885
2 1/4 2.2500	.0120	.015	2.277	2.262
2 5/8 2.6250	.0140	.017	2.656	2.639
3 3.0000	.0160	.019	3.035	3.016
3 3/8 3.3750	.0180	.021	3.414	3.393
3 3/4 3.7500	.0200	.023	3.793	3.770
4 1/8 4.1250	.0220	.024	4.171	4.147
4 1/2 4.5000	.0230	.026	4.549	4.523

The sizes given in the table for the maximum and minimum columns are sizes of Go and Not-go gage blocks used for inspecting wrenches and are not product sizes.

Wrenches shall be marked with the basic width (maximum width of nut) across flats, as shown in column 1.



Hot-Pressed and Cold-Punched Nuts

Effective Sept. 1, 1923
(Dimensions in Inches)

U. S. Standard Hot-Pressed and Cold-Punched Nuts				Cold-Punched Check and Jam Nuts			
Hexagon and Square				Hexagon			
Diam. Bolt	Across Flats	Thickness	Diam. Hole	Diam. Bolt	Across Flats	Thickness	Diam. Hole
1/4	3/8	1/4	13/64	1/4	9/16	5/16	13/64
5/16	1/2	5/16	17/64	5/16	5/8	3/8	17/64
3/8	9/16	11/32	5/16	3/8	11/16	7/16	5/16
7/16	5/8	25/64	29/64	7/16	3/4	1/2	29/64
1/2	3/4	7/16	33/64	1/2	7/8	9/16	33/64
9/16	13/16	1/2	37/64	9/16	15/16	5/8	37/64
5/8	15/16	9/16	41/64	5/8	1 1/16	11/16	41/64
3/4	1 1/8	5/8	49/64	3/4	1 1/4	13/16	49/64
7/8	1 5/16	3/4	57/64	7/8	1 7/16	15/16	57/64
1	1 1/2	7/8	1 1/64	1	1 5/8	1	1 1/64
1 1/8	1 11/16	1	1 9/64	1 1/8	1 13/16	1 1/16	1 9/64
1 1/4	1 7/8	1 1/8	1 17/64	1 1/4	2	1 1/8	1 17/64
1 3/8	2 1/16	1 1/4	1 25/64	1 3/8	2 3/16	1 3/16	1 25/64
1 1/2	2 1/4	1 3/8	1 33/64	1 1/2	2 3/8	1 5/16	1 33/64
1 5/8	2 7/16	1 1/2	1 41/64	1 5/8	2 9/16	1 7/16	1 41/64
1 3/4	2 5/8	1 5/8	1 49/64	1 3/4	2 3/4	1 1/2	1 49/64
1 7/8	2 13/16	1 3/4	1 57/64	1 7/8	2 15/16	1 5/8	1 57/64
2	3	2	2 1/32	2	3 1/8	1 3/4	2 1/32
2 1/4	3 3/8	2 1/4	2 9/32				
2 1/2	3 3/4	2 1/2	2 17/32				
2 3/4	4 1/8	2 3/4	2 25/32				
3	4 1/2	3	2 29/32				

These are given to show the former standards of one of the manufacturers.

HOT-PRESSED AND COLD-PUNCHED NUTS (*Continued*)

HEXAGON NUTS, SEMI-FINISHED					SQUARE AND HEXAGON NUTS, BOLT SIZES	
Bolt Diam.	Number of Threads	Diameter across Flats	Thickness		Across Flats	Thick
			Standard	Jam		
$\frac{1}{4}$	20	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{7}{16}$	$\frac{7}{32}$
$\frac{5}{16}$	18	$\frac{9}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$
$\frac{3}{8}$	16	$\frac{11}{16}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{9}{16}$	$\frac{5}{16}$
$\frac{7}{16}$	14	$\frac{25}{32}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{21}{32}$	$\frac{5}{16}$
$\frac{1}{2}$	13	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{7}{16}$
$\frac{9}{16}$	12	$\frac{31}{32}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{27}{32}$	$\frac{7}{16}$
$\frac{5}{8}$	11	$1\frac{1}{16}$	$\frac{5}{8}$	$\frac{1}{2}$	1	$\frac{1}{2}$
$\frac{3}{4}$	10	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{9}{16}$	$1\frac{3}{16}$	$\frac{5}{8}$
$\frac{7}{8}$	9	$1\frac{7}{16}$	$\frac{7}{8}$	$\frac{5}{8}$	$1\frac{3}{8}$	$\frac{3}{4}$
1	8	$1\frac{5}{8}$	1	$\frac{11}{16}$	$1\frac{5}{8}$	$\frac{7}{8}$
$1\frac{1}{8}$	7	$1\frac{13}{16}$	$1\frac{1}{8}$	$\frac{3}{4}$		
$1\frac{1}{4}$	7	2	$1\frac{1}{4}$	$\frac{13}{16}$		
$1\frac{3}{8}$	6	$2\frac{3}{16}$	$1\frac{3}{8}$	$\frac{7}{8}$		
$1\frac{1}{2}$	6	$2\frac{3}{8}$	$1\frac{1}{2}$	1		
$1\frac{5}{8}$	$5\frac{1}{2}$	$2\frac{9}{16}$	$1\frac{5}{8}$	$1\frac{1}{16}$		
$1\frac{3}{4}$	5	$2\frac{3}{4}$	$1\frac{3}{4}$	1		
$1\frac{7}{8}$	5	$2\frac{15}{16}$	$1\frac{7}{8}$	$1\frac{1}{16}$		
2	$4\frac{1}{2}$	$3\frac{1}{8}$	2	$1\frac{1}{8}$		
$2\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{1}{4}$		
$2\frac{1}{2}$	4	$3\frac{7}{8}$	$2\frac{1}{2}$	$1\frac{3}{8}$		
$2\frac{3}{4}$	4	$4\frac{1}{4}$	$2\frac{3}{4}$	$1\frac{1}{2}$		
3	$3\frac{1}{2}$	$4\frac{5}{8}$	3	2		

(From tables by Hoopes & Townsend Co.)

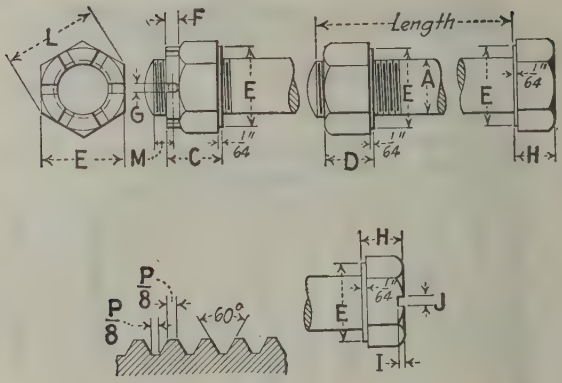
SCREWS, BOLTS AND NUTS

S. A. E. Standard

The length of the effective thread of screws and bolts shall be: $1\frac{1}{2}$ diameter + $\frac{1}{4}$ inch. As bolts and screws conforming to these specifications are primarily intended for use with nuts, the oval end is not included in the nominal length.

All beads and nuts shall be semi-finished. All screws and nuts shall be made of steel.

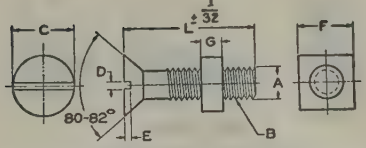
S. A. E. Standard bolts without slots or cotter-pin holes are made for stock. If slots, cotter-pin holes or case hardening are desired, these should be specified by the purchaser.



SCREW, BOLT AND NUT DIMENSIONS
(All Dimensions in Inches)

Diam. *A* — 0.001 — 0.003	Threads per Inch, *B*	*C*	*D*	*E*[1]	*F*	*G*[2]	*H*	*I*	*J*	*K*[3]	*L*	Cotter-Pin Hole	*M*
1/4	28	9/32	7/32	7/16	3/32	5/64	3/16	3/32	1/16	1/16	1/2	5/64	3/32
5/16	24	21/64	17/64	1/2	3/32	5/64	15/64	7/64	1/16	1/16	37/64	5/64	3/32
3/8	24	13/32	21/64	9/16	1/8	1/8	9/32	1/8	3/32	3/32	21/32	1/8	7/64
7/16	20	29/64	5/8	5/8	1/8	1/8	21/64	1/8	3/32	3/32	23/32	1/8	7/64
1/2	20	9/16	7/16	3/4	3/16	1/8	3/8	1/8	3/32	3/32	7/8	5/32	1/8
9/16	18	39/64	31/64	7/8	3/16	5/32	27/64	1/8	3/32	1/8	1 1/64	5/32	9/64
5/8	18	25/32	35/64	15/16	1/4	5/32	15/32	1/8	3/32	1/8	1 3/32	5/32	5/32
3/4	16	13/16	21/32	1 1/16	1/4	5/32	9/16	1/8	3/32	1/8	1 5/64	5/32	3/16
7/8	14	29/32	49/64	1 1/4	1/4	5/32	21/32	1/8	3/32	1/8	1 7/16	5/32	3/16
1	14	1	7/8	1 7/16	1/4	5/32	3/4	1/8	3/32	1/8	1 21/32	5/32	3/16
1 1/8	12	1 5/32	63/64	1 5/8	5/16	7/32	27/32	7/32	3/32	11/64	1 13/16	7/32	7/32
1 1/4	12	1 1/4	1 3/32	1 13/16	5/16	7/32	15/16	7/32	3/32	11/64	2 3/32	7/32	7/32
1 3/8	12	1 13/32	1 13/64	2	3/8	1/4	1 1/32	1/4	3/16	13/64	2 5/16	1/4	1/4
1 1/2	12	1 1/2	1 5/16	2 3/16	3/8	1/4	1 1/8	1/4	1/16	13/64	2 17/32	1/4	1/4

[1] For S. A. E. nuts, bolt and screw heads.
[2] Width of slots in nuts.
[3] Cotter-pin diameter.

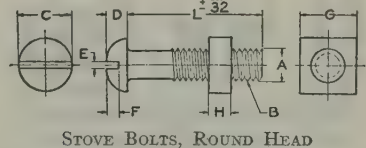


STOVE BOLTS, FLAT HEAD

CLASS 1, LOOSE FIT, COARSE THREADS

(All Dimensions in Inches)

A	Basic major dia.....	1/8 (#5)	5/32 (#8)	3/16 (#10)	7/32 (#12)	1/4	5/16	3/8
	Max. major dia.....	.1240	.1629	.1887	.2147	.2485	.3109	.3732
	Min. major dia.....	.1172	.1553	.1795	.2055	.2383	.2995	.3606
B	Threads per inch.....	40	32	24	24	20	18	16
	Max. pitch dia.....	.1078	.1426	.1616	.1876	.2160	.2748	.3326
	Min. pitch dia.....	.1044	.1388	.1570	.1830	.2109	.2691	.3263
C	Max. head dia.....	.252	.332	.376	.438	.490	.629	.742
	Min. head dia.....	.232	.308	.350	.410	.460	.594	.702
D	Max. slot width.....	.044	.051	.056	.060	.067	.078	.089
	Min. slot width.....	.030	.036	.040	.044	.050	.060	.071
E	Max. slot depth.....	.034	.045	.053	.060	.070	.088	.106
	Min. slot depth.....	.022	.029	.034	.039	.046	.058	.070
F	Nut width.....	1/4	11/32	3/8	7/16	1/2	9/16	5/8
G	Nut thickness.....	7/64	1/8	5/32	5/32	3/16	1/4	1/4

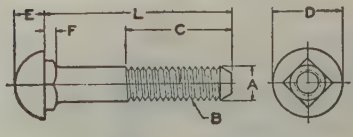


STOVE BOLTS, ROUND HEAD

CLASS 1, LOOSE FIT, COARSE THREADS

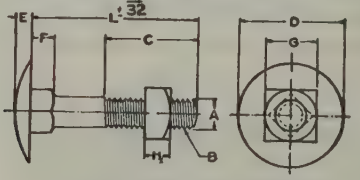
(All Dimensions in Inches)

A	Basic major dia.....	1/8 (#5)	5/32 (#8)	3/16 (#10)	7/32 (#12)	1/4	5/16	3/8
	Max. major dia.....	.1240	.1629	.1887	.2147	.2485	.3109	.3732
	Min. major dia.....	.1172	.1553	.1795	.2055	.2383	.2995	.3606
B	Threads per inch.....	40	32	24	24	20	18	16
	Max. pitch dia.....	.1078	.1426	.1616	.1876	.2160	.2748	.3326
	Min. pitch dia.....	.1044	.1388	.1570	.1830	.2109	.2691	.3263
C	Max. head dia.....	.236	.309	.358	.407	.471	.567	.674
	Min. head dia.....	.217	.287	.335	.382	.444	.535	.636
D	Max. head thickness..	.082	.102	.132	.137	.163	.201	.240
	Min. head thickness..	.070	.090	.120	.125	.150	.187	.225
E	Max. slot width.....	.044	.051	.056	.060	.067	.078	.089
	Min. slot width.....	.030	.036	.040	.044	.050	.060	.071
F	Max. slot depth.....	.062	.076	.086	.095	.108	.130	.153
	Min. slot depth.....	.047	.057	.064	.071	.080	.097	.114
G	Nut width.....	1/4	11/32	3/8	7/16	1/2	9/16	5/8
H	Nut thickness.....	7/64	1/8	5/32	5/32	3/16	1/4	1/4



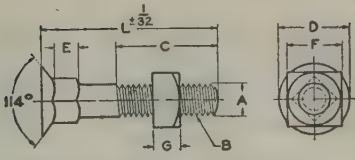
HUB BOLTS
(All Dimensions in Inches)

	Coarse Threads	Class 2, Free Fit			Class 3, Medium Fit		
A	Basic major dia.	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
	Max. major dia.	.3750	.4375	.5000	.3750	.4375	.5000
	Min. major dia.	.3660	.4277	.4896	.3660	.4277	.4896
B	Threads per inch.	16	14	13	16	14	13
	Max. pitch dia.	.3344	.3911	.4500	.3344	.3911	.4500
	Min. pitch dia.	.3299	.3862	.4448	.3312	.3875	.4463
C	Thread length.	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{1}{2}$
D	Head dia.	$\frac{13}{16}$	$\frac{15}{16}$	1	$\frac{13}{16}$	$\frac{15}{16}$	1
E	Head thickness.	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$
F	Length of square.	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$



STEP BOLTS—AMERICAN STANDARD
CLASS 2, FREE FIT, COARSE THREADS
(All Dimensions in Inches)

		Bolt with Nut			Bolt without Nut		
A	Basic major dia.	$\frac{1}{2}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{16}$	$\frac{3}{8}$
	Max. major dia.	.2500	.3125	.3750	.2500	.3125	.3750
	Min. major dia.	.2398	.3011	.3660	.2398	.3011	.3660
B	Threads per inch.	20	18	16	20	18	16
	Max. pitch dia.	.2175	.2764	.3344	.2175	.2764	.3344
	Min. pitch dia.	.2139	.2723	.3299	.2139	.2723	.3299
C	Thread length, min.	$\frac{3}{4}$	$\frac{13}{16}$	$1\frac{1}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$1\frac{1}{8}$
D	Head diameter.	$\frac{13}{16}$	1	$1\frac{3}{16}$	$\frac{13}{16}$	1	$1\frac{3}{16}$
E	Head thickness.	$\frac{1}{4}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{32}$	$\frac{3}{16}$
F	Length of square.	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$
	Tensile strength, lbs.	130	225	340	130	225	340
	Shearing strength, lbs.	245	383	552	245	383	552
G	Nut width.	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{5}{8}$
H	Nut thickness.	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{5}{16}$

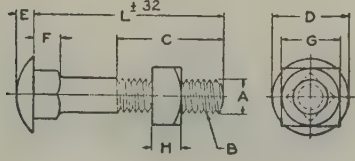


Carriage Bolts, Flat Countersunk Head

CLASS 2, FREE FIT, COARSE THREADS

(All Dimensions in Inches)

A	Basic major dia	1/4	5/16	3/8	7/16	1/2
	Max. major dia	.2500	.3125	.3750	.4375	.5000
	Min. major dia	.2398	.3011	.3624	.4235	.4852
B	Threads per inch	20	18	16	14	13
	Max. pitch dia	.2175	.2764	.3344	.3911	.4500
	Min. pitch dia	.2139	02723	.3299	.3862	.4448
C	Thread length, min	3/4	7/8	1 1/4	1 3/16	1 1/2
D	Head diameter	1/2	5/8	3/4	1	1 1/4
E	Length of square	3/32	1/8	3/32	1/8	3/32
F	Nut width	1/16	1/16	1/8	3/32	1/16
G	Nut thickness	3/32	1/8	1/16	1/8	1/16

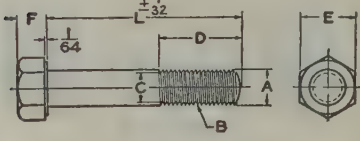


Carriage Bolts, Round Head

CLASS 2, FREE FIT, COARSE THREADS

(All Dimensions in Inches)

A	Basic major dia	3/16 (#10)	1/4	5/16	3/8	7/16	1/2
	Max. major dia	.1900	.2500	.3125	.3750	.4300	.5000
	Min. major dia	.1808	.2398	.3011	.3624	.4235	.4852
B	Threads per inch	24	20	18	16	14	13
	Max. pitch dia	.1629	.2175	.2764	.3344	.3911	.4500
	Min. pitch dia	.1596	.2139	.2723	.3299	.3862	.4448
C	Thread length, min	5/8	3/4	7/8	1 1/8	1 1/8	1 1/2
D	Head diameter	7/16	5/8	11/16	13/16	15/16	1 1/16
E	Head thickness	3/32	1/8	5/32	3/16	7/32	1/4
F	Length of square	1/8	3/16	7/32	1/4	9/32	11/32
G	Nut width	1/8	3/16	1/4	5/16	11/32	13/32
H	Nut thickness	5/32	1/8	11/64	1/4	19/64	11/32



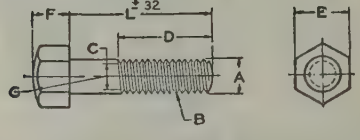
Bolts, Hexagon Head, Semi-finished

class 2, free fit, fine threads

(All Dimensions in Inches)

A	Basic major dia.	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8
	Max. major dia.	.2500	.3125	.3750	.4375	.5000	.5625	.6250	.7500	.8750
	Min. major dia.	.2438	.3059	.3684	.4303	.4928	.5543	.6168	.7410	.8652
B	Threads per inch	28	24	24	20	20	18	18	16	14
	Max. pitch dia.	.2268	.2854	.3479	.4050	.4675	.5264	.5889	.7094	.8286
	Min. pitch dia.	.2237	.2821	.3446	.4014	.4639	.5223	.5848	.7049	.8237
C	Max. minor dia.	.2062	.2614	.3239	.3762	.4387	.4943	.5568	.6733	.7874
D	Thread length	1/2	5/8	3/4	29/32	1	1 1/32	1 1/16	1 1/4	1 7/16
E	Head width	7/16	1/2	9/16	5/8	3/4	7/8	15/16	1 1/16	1 1/4
F	Head thickness	7/16	35/64	1/2	9/16	21/32	27/64	1/2	43/64	3/4

A	Basic major dia.	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2
	Max. major dia.	1.0000	1.1250	1.2500	1.3750	1.5000	1.6250	1.7500	1.8750	2.0000
	Min. major dia.	.9848	1.1086	1.2336	1.3568	1.4818	1.6055	1.7305	1.8541	1.9791
B	Threads per inch	8	7	7	6	6	5½	5	5	4½
	Max. pitch dia.	.9188	1.0322	1.1572	1.2667	1.3917	1.5035	1.6285	1.7388	1.8638
	Min. pitch dia.	.9112	1.0237	1.1487	1.2568	1.3818	1.4921	1.6171	1.7260	1.8510
C	Max. minor dia.	.8466	.9497	1.0747	1.1705	1.2955	1.3863	1.5113	1.6041	1.7291
D	Thd. lgth., min.	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/4
E	Head width	1 1/2	1 11/16	1 7/8	2 1/16	2 1/4	2 7/16	2 5/8	2 13/16	3
F	Head thickness	1	1 1/16	1 1/8	1 3/16	1 5/16	1 7/16	1 1/2	1 5/8	1 3/4
G	Head radius	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1



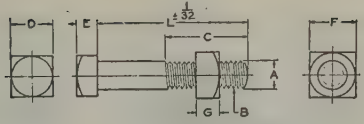
Cap Screws, Hexagon Head, Semi-finished

class 2, free fit, coarse threads

(All Dimensions in Inches)

A	Basic major dia.	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8
	Max. major dia.	.2500	.3125	.3750	.4375	.5000	.5625	.6250	.7500	.8750
	Min. major dia.	.2428	.3043	.3660	.4277	.4896	.5513	.6132	.7372	.8610
B	Threads per inch	20	18	16	14	13	12	11	10	9
	Max. pitch dia.	.2175	.2764	.3344	.3911	.4500	.5084	.5660	.6850	.8028
	Min. pitch dia.	.2139	.2723	.3299	.3862	.4448	.5028	.5601	.6786	.7958
C	Max. minor dia.	.1887	.2443	.2983	.3499	.4056	.4603	.5135	.6273	.7387
D	Thd. lgth., min.	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2
E	Head width	7/16	1/2	9/16	5/8	3/4	13/16	7/8	1	1 1/8
F	Head thickness	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8
G	Head radius	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 1/2	1 3/4

A	Basic major dia.	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2
	Max. major dia.	1.0000	1.1250	1.2500	1.3750	1.5000	1.6250	1.7500	1.8750	2.0000
	Min. major dia.	.9848	1.1086	1.2336	1.3568	1.4818	1.6055	1.7305	1.8541	1.9791
B	Threads per inch	8	7	7	6	6	5½	5	5	4½
	Max. pitch dia.	.9188	1.0322	1.1572	1.2667	1.3917	1.5035	1.6285	1.7388	1.8638
	Min. pitch dia.	.9112	1.0237	1.1487	1.2568	1.3818	1.4921	1.6171	1.7260	1.8510
C	Max. minor dia.	.8466	.9497	1.0747	1.1705	1.2955	1.3863	1.5113	1.6041	1.7291
D	Thd. lgth., min.	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/4
E	Head width	1 1/2	1 11/16	1 7/8	2 1/16	2 1/4	2 7/16	2 5/8	2 13/16	3
F	Head thickness	1	1 1/16	1 1/8	1 3/16	1 5/16	1 7/16	1 1/2	1 5/8	1 3/4
G	Head radius	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3

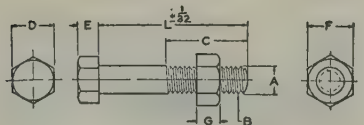


Machine Bolts, Square Head

CLASS 2, FREE FIT, COARSE THREADS

(All Dimensions in Inches)

A	Basic major dia.	1/4	5/16	3/8	7/16	1/2
	Max. major dia.	.2500	.3125	.3750	.4375	.5000
	Min. major dia.	.2428	.3043	.3660	.4277	.4896
B	Threads per inch.	20	18	16	14	13
	Max. pitch dia.	.2175	.2764	.3344	.3911	.4500
	Min. pitch dia.	.2139	.2723	.3299	.3862	.4448
C	Thread length.	3/4	7/8	1 1/8	1 1/4	1 3/8
D	Head width.	3/8	7/16	9/16	21/32	3/4
E	Head thickness.	5/16	27/64	17/32	31/64	7/16
F	Nut width.	7/16	9/16	5/8	23/32	13/16
G	Nut thickness.	7/32	1/4	5/16	3/8	7/16

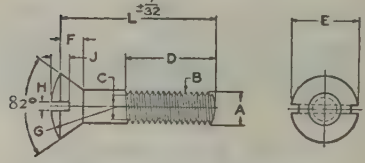


Machine Bolts, Hexagon Head

CLASS 2, FREE FIT, COARSE THREADS

(All Dimensions in Inches)

A	Basic major dia.	1/4	5/16	3/8	7/16	1/2
	Max. major dia.	.2500	.3125	.3750	.4375	.5000
	Min. major dia.	.2428	.3043	.3660	.4277	.4896
B	Threads per inch.	20	18	16	14	13
	Max. pitch dia.	.2175	.2764	.3344	.3911	.4500
	Min. pitch dia.	.2139	.2723	.3299	.3862	.4448
C	Thread length.	3/4	7/8	1 1/8	1 1/4	1 3/8
D	Head width.	3/8	7/16	9/16	21/32	3/4
E	Head thickness.	5/16	27/64	17/32	31/64	7/16
F	Nut width.	7/16	9/16	5/8	23/32	13/16
G	Nut thickness.	7/32	1/4	5/16	3/8	7/16

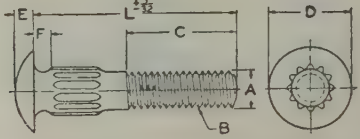


Cap Screws, Oval Head

Class 2, free fit, coarse threads

(All Dimensions in Inches)

A	Basic major dia.	1/4	5/16	3/8	7/16	1/2
	Max. major dia.	.2500	.3125	.3750	.4375	.5000
	Min. major dia.	.2428	.3043	.3660	.4277	.4896
B	Threads per inch.	20	18	16	14	13
	Max. pitch dia.	.2175	.2764	.3344	.3911	.4500
	Min. pitch dia.	.2139	.2723	.3299	.3862	.4448
C	Max. minor dia.	.1887	.2443	.2983	.3499	.4056
D	Thread length.	3/4	7/8	1	1 1/8	1 1/4
E	Head diameter	1/2	5/8	3/4	13/16	7/8
F	Head thickness	11/64	7/32	17/64	31/64	17/32
G	Head radius	1/16	1/8	3/16	1/4	5/16
H	Slot width	1/16	1/16	3/32	3/32	1/8
J	Slot depth	1/8	5/32	3/16	7/32	1/4

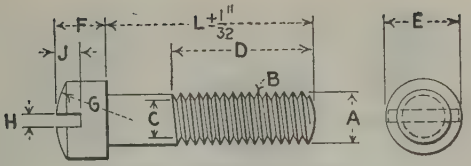


Carriage Bolts, Ribbed Neck

Class 2, free fit, coarse threads

(All Dimensions in Inches)

A	Basic major dia.	1/4	5/16	3/8	7/16	1/2
	Max. major dia.	.2500	.3125	.3750	.4375	.5000
	Min. major dia.	.1808	.2398	.3624	.4235	.4852
B	Threads per inch.	20	18	16	14	13
	Max. pitch dia.	.2175	.2764	.3344	.3911	.4500
	Min. pitch dia.	.2139	.2723	.3299	.3862	.4448
C	Thread length, min	3/4	7/8	1	1 1/16	1 1/4
D	Head diameter	9/16	11/16	13/16	15/16	1 1/16
E	Head thickness	1/4	5/16	3/8	7/16	1/2
F	Head to ribs	1/4	5/16	3/8	1/2	1/2

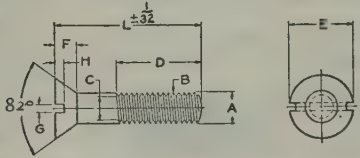


Cap Screws, Fillister Head

CLASS 2, FREE FIT, COARSE THREADS

(All Dimensions in Inches)

A	Basic major dia	1/4	5/16	3/8	7/16	1/2
	Max. major dia	.2500	.3125	.3750	.4375	.5000
	Min. major dia	.2428	.3043	.3660	.4277	.4896
B	Threads per inch	20	18	16	14	13
	Max. pitch dia	.2175	.2764	.3344	.3911	.4500
	Min. pitch dia	.2139	.2723	.3299	.3862	.4448
C	Max. minor dia	.1887	.2443	.2983	.3499	.4056
D	Thread length	3/4	7/8	1	1 1/8	1 1/4
E	Head dia	3/8	7/16	9/16	5/8	3/4
F	Head thickness	1/4	5/16	3/8	7/16	1/2
G	Head radius	3/32	7/64	9/64	5/32	3/16
H	Slot width	1/16	5/64	3/32	7/64	1/8
J	Slot depth	1/8	5/64	3/16	7/32	1/4

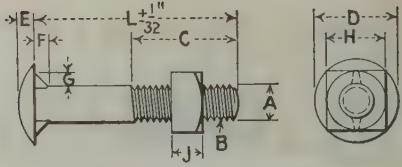


Cap Screws, Flat Head

CLASS 2, FREE FIT, COARSE THREADS

(All Dimensions in Inches)

A	Basic major dia	1/4	5/16	3/8	7/16	1/2
	Max. major dia	.2500	.3125	.3750	.4375	.5000
	Min. major dia	.2428	.3043	.3660	.4277	.4896
B	Threads per inch	20	18	16	14	13
	Max. pitch dia	.2175	.2764	.3344	.3911	.4500
	Min. pitch dia	.2139	.2723	.3299	.3862	.4448
C	Max. minor dia	.1887	.2443	.2983	.3499	.4056
D	Thread length	3/4	7/8	1	1 1/8	1 1/4
E	Head dia	15/32	17/32	21/32	25/32	7/8
F	Head thickness	11/64	7/32	17/64	19/64	11/64
G	Slot width	1/16	5/64	3/32	7/64	1/8
H	Slot depth	9/64	11/64	7/64	1/8	5/32

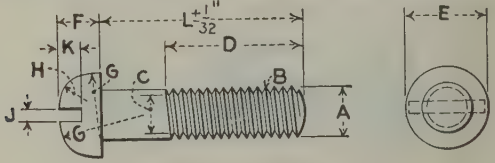


Carriage Bolts, Fin Neck

CLASS 2, FREE FIT, COARSE THREADS

(All Dimensions in Inches)

		Bolt with Nut			Bolt without Nut		
A	Basic major dia.	1/4	5/16	3/8	1/4	5/16	3/8
	Max. major dia.	.2500	.3125	.3750	.2500	.3125	.3750
	Min. major dia.	.2398	.3011	.3624	.2398	.3011	.3624
B	Threads per inch.	20	18	16	20	18	16
	Max. pitch dia.	.2175	.2764	.3344	.2175	.2764	.3344
	Min. pitch dia.	.2139	.2723	.3299	.2139	.2723	.3299
C	Thread length, min.	3/4	7/8	1	3/4	7/8	1
D	Head diameter	7/16	9/16	11/16	7/16	9/16	11/16
E	Head thickness	11/32	13/32	15/32	11/32	13/32	15/32
F	Head to ribs	1/8	1/16	1/8	1/8	1/16	1/8
F	Fin. height	3/32	1/8	3/32	3/32	1/8	3/32
G	Fin. width	3/32	1/16	1/8	3/32	1/16	1/8
H	Nut width	7/16	9/16	5/8	7/16	9/16	5/8
J	Nut thickness	11/32	1/4	5/16	11/32	1/4	5/16



Cap Screws, Round (Button) Head

CLASS 2, FREE FIT, COARSE THREADS

(All Dimensions in Inches)

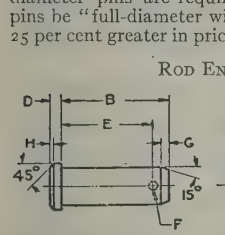
A	Basic major dia.	1/4	5/16	3/8	7/16	1/2
	Max. major dia.	.2500	.3125	.3750	.4375	.5000
	Min. major dia.	.2428	.3043	.3660	.4277	.4896
B	Threads per inch.	20	18	16	14	13
	Max. pitch dia.	.2175	.2764	.3344	.3011	.4500
	Min. pitch dia.	.2139	.2723	.3299	.3862	.4448
C	Max. minor dia.	.1887	.2443	.2983	.3499	.4050
D	Thread length	3/4	7/8	1	1 1/8	1 1/4
E	Head dia.	7/16	9/16	5/8	3/4	13/16
F	Head thickness	7/32	9/32	5/16	3/8	7/16
G	Head radius	1/16	1/16	1/8	3/16	3/16
H	Head radius	1/8	3/32	1/16	3/32	1/4
J	Slot width	1/8	1/16	3/32	1/16	1/16
K	Slot depth	1/8	3/32	1/16	3/32	1/4

Cotter Pins, S. A. E. Standard

Three points are used which are optional: the standard point, the double-bevel point and the extended prong. There is no difference in the cost of pins with either of these points.

These pins are slightly smaller in diameter than the nominal diameter given, as this practice has become standard with all cotter-pin manufacturers. When pins are ordered of a certain nominal diameter, the undersize pins are furnished. Where full-diameter pins are required the purchaser must specify that these pins be "full-diameter wire." The latter, however, run from 14 to 25 per cent greater in price than the standard undersize pins.

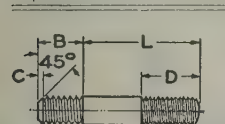
Rod End Pins, S. A. E. Standard



The standard pins are made of commercial cold-rolled steel. The hardened pins are made of S. A. E. 1010 steel or equivalent and are cyanide hardened.

(All Dimensions in Inches)

A	Nominal diameter	5/32	1/4	5/16	3/8	7/16	1/2
	Max. diameter	.186	.248	.311	.373	.436	.496
	Min. diameter	.181	.243	.306	.368	.431	.491
B	Length	13/16	1 1/16	1 5/16	1 9/16	1 13/16	2 1/16
C	Head diameter	3/8	1/2	5/8	3/4	7/8	1
D	Head thickness	1/16	7/64	1/16	1/16	1/16	1/16
E	To hole	11/16	15/16	1 3/16	1 7/16	1 11/16	1 15/16
F	Drill diameter	3/64	3/64	1/16	1/16	1/16	5/64
		#48 (.076)	#48 (.076)	#36 (.106)	#36 (.106)	#36 (.106)	#28 (.140)
G	Chamfer	1/64	1/16	1/64	1/64	1/32	1/64
H	Chamfer	1/64	1/32	1/32	1/32	1/64	1/64
	Weight, lbs. per 1,000						



Studs—G.M.C. Studs 1925

(Dimensions in Inches)

	A Stud Diameter	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4
Stud End	Threads per inch	20	18	16	14	13	12	11	10
	Thread length *B*	3/8	1/2	9/16	11/16	3/4	7/8	15/16	1 1/8
	Max. pitch diam.	.221	.280	.338	.395	.454	.513	.571	.690
	Min. pitch diam.	.219	.278	.336	.393	.452	.510	.568	.687
	Chamfer *C*	1/32	1/32	3/64	3/64	1/16	1/16	3/32	3/32
Nut End	Threads per inch	28	24	24	20	20	18	18	16
	Thread length *D*	7/16	9/16	5/8	3/4	13/16	7/8	15/16	1 1/16
	Max. pitch diam.	.2268	.2854	.3479	.4050	.4675	.5264	.5889	.7094
	Min. pitch diam.	.2237	.2821	.3446	.4014	.4639	.5223	.5848	.7049

Experiments as to the depth of thread (not depth of hole) show that the tap drill can be much larger than is generally supposed and still hold the stud against stripping, even in aluminum. Tests show that a 43 per cent depth of thread in aluminum will break a $\frac{5}{16}$-inch stud before stripping, when the stud is a good fit, or, in other words, when the stud is 0.003 in. larger than tapped hole.

The depth of the hole also has its effect, but a depth of $1\frac{1}{2}$ diameters is sufficient for most materials, unless the stud has to carry an appreciable fatigue stress. In that case 2 diameters will be better.

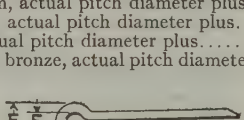
The "lute" or material used on the threads in setting studs also affects the torque. White lead is frequently used with iron or steel, and oil with aluminum. One motor builder uses kerosene in the latter case.

There is a tendency toward using ground taps and chasers for stud holes and studs which are held to very close limits, as these give greater area of contact and the studs hold better. Some use a commercial tap first and finish with a ground tap. Some advocate a four-fluted tap with narrow lands for cast iron and a three-fluted tap with wider lands for steel and aluminum. Some rough tap by machine and leave 0.010 inch for a hand-finishing tap. Holes are tapped straight in almost every case, but one builder of large machinery uses a taper of $\frac{1}{2}$ inch per foot.

The chamfering of the end of studs also plays a part. Some contend that a chamfer of 90 degrees included angle throws up a burr on the first thread, which makes a stud drive hard but allows it to unscrew easily. They prefer the 60-degree included angle.

Another authority gives the following allowances for the stud end in order to insure a tight fit in different materials:

For aluminum, actual pitch diameter plus..... 0.004–0.006 inch.
For cast iron, actual pitch diameter plus..... 0.002–0.004 inch.
For steel, actual pitch diameter plus..... 0.001–0.003 inch.
For brass and bronze, actual pitch diameter plus 0.003–0.005 inch.



STANDARD COTTER PINS
GENERAL MOTORS CO.
(Dimensions in Inches)

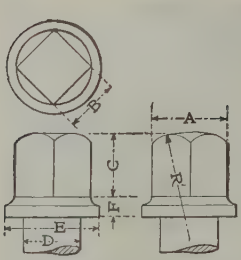
D	Nominal dia...	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{5}{64}$	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{1}{8}$	$\frac{9}{64}$	$\frac{5}{32}$	$\frac{3}{16}$
	Actual dia. min.	.042	.058	.086	.118	.146	.172	.202	.220	.275
	Actual dia. max.	.045	.061	.090	.122	.150	.176	.207	.225	.280
E	Inside dia., of eye.....	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{5}{16}$
F	Outside dia., of eye (approx.).	$\frac{7}{64}$	$\frac{5}{32}$	$\frac{7}{32}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$
	Drill dia.....	#52 (.0635)	#48 (.076)	#36 (.1065)	#28 (.1405)	#17 (.173)	#7 (.201)	B (.238)	$\frac{9}{32}$	$\frac{11}{32}$

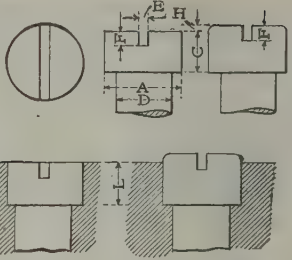
Tolerance—plus or minus 0.010 inch.

Cotters Used in Bolts or Rod Ends—Cotter Pins—S. A. E. Standards for Bolts

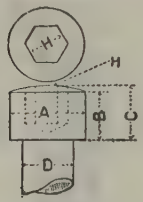
(Dimensions in Inches)

Bolt or Rod-End Pin Diam.	American Bolts					S. A. E. Bolts		
	Cotter Diam.	B.W.G. Gage	Cotter Length		Drill No.	Cotter Length		Drill No.
			Short	Long		Short	Long	
$\frac{1}{4}$	$\frac{1}{16}$		$\frac{1}{2}$	$\frac{5}{8}$	48	$\frac{1}{2}$	$\frac{5}{8}$	48
$\frac{5}{16}$	$\frac{1}{16}$		$\frac{5}{8}$	$\frac{3}{4}$	48	$\frac{5}{8}$	$\frac{3}{4}$	48
$\frac{3}{8}$	$\frac{3}{32}$		$\frac{3}{4}$	$\frac{7}{8}$	36	$\frac{5}{8}$	$\frac{3}{4}$	36
$\frac{7}{16}$	$\frac{3}{32}$	13	3	1	36	5	3	36
$\frac{1}{2}$	$\frac{3}{32}$		$\frac{7}{8}$	$1\frac{1}{8}$	36	$\frac{3}{4}$	$\frac{7}{8}$	36
$\frac{9}{16}$	$\frac{1}{8}$		1	$1\frac{1}{4}$	30	$\frac{7}{8}$	$1\frac{1}{8}$	28
$\frac{5}{8}$	$\frac{1}{8}$	11	$1\frac{1}{8}$	$1\frac{3}{8}$	30	1	$1\frac{1}{4}$	28
$\frac{11}{16}$			$1\frac{1}{8}$	$1\frac{3}{8}$	30			
$\frac{3}{4}$	$\frac{1}{8}$		$1\frac{1}{4}$	$1\frac{1}{2}$	28	$1\frac{1}{8}$	$1\frac{3}{8}$	28
$\frac{7}{8}$	$\frac{1}{8}$	11	$1\frac{3}{8}$	$1\frac{3}{4}$	21	$1\frac{1}{4}$	$1\frac{1}{2}$	28
1	$\frac{1}{8}$	8	$1\frac{5}{8}$	2	21	$1\frac{1}{2}$	$1\frac{3}{4}$	28
$1\frac{1}{8}$	$\frac{11}{64}$		$1\frac{3}{4}$	$2\frac{1}{4}$	11	$1\frac{5}{8}$	2	11
$1\frac{1}{4}$	$\frac{11}{64}$	8	2	$2\frac{1}{2}$	11	$1\frac{3}{4}$	$2\frac{1}{4}$	11
$1\frac{3}{8}$	$\frac{13}{64}$	6	$2\frac{1}{4}$	$2\frac{3}{4}$	2	2	$2\frac{1}{2}$	2
$1\frac{1}{2}$	$\frac{13}{64}$		$2\frac{1}{4}$	3	2	$2\frac{1}{4}$	$2\frac{3}{4}$	2





Collar Head Screws								Fillister Head Cap Screws (P. & .W. St'd)						
Dia. of Screw	No. of Threads per Inch	Distance Across Corners	Distance Across Flats	Length of Head	Dia. of Collar	Thickness of Collar	Radius of Head	Dia. of Head	Length of Flat Head	Height of Round Corner	Length of Round Head	Width of Slot	Depth of Slot	Depth of Counterbore
D		A	B	C	E	F	R	A	C	H	C+H	E	F	L
1/8	40	11/64	1/8	9/64	1/4	7/16	1/4	11/64	3/32	1/32	1/8	.025	1/32	3/32
3/16	32	17/64	3/16	7/32	11/32	5/64	3/8	1/4	1/8	1/32	5/32	.039	3/64	1/8
1/4	20	11/32	1/4	9/32	7/16	11/32	1/2	11/32	5/32	1/32	3/16	.058	5/64	5/32
5/16	18	7/16	5/16	11/32	1/2	1/8	11/16	7/16	3/16	3/64	15/64	.071	5/64	3/16
3/8	16	17/32	3/8	13/32	5/8	5/32	13/16	1/2	1/4	3/64	19/64	.086	7/64	1/4
7/16	14	5/8	7/16	15/32	11/16	3/16	15/16	9/16	1/4	3/64	19/64	.099	7/64	1/4
1/2	13	45/64	1/2	17/32	13/16	13/64	1 1/16	11/16	5/16	3/64	23/64	.112	1/8	5/16
9/16	12	51/64	9/16	5/8	15/16	7/32	1 3/16	3/4	3/8	3/64	23/64	.133	9/64	3/8
5/8	11	57/64	5/8	11/16	1	1/4	1 5/16	7/8	7/16	1/16	1/2	.133	5/32	7/16
3/4	10	1 1/16	3/4	13/16	1 1/4	5/16	1 9/16	1 1/16	1/2	1/16	9/16	.133	3/16	1/2
7/8	9							1 3/16	9/16	1/16	5/8	.133	7/32	9/16
1	8							1 3/8	5/8	1/16	11/16	.165	1/4	5/8



ALLEN SAFETY SET SCREWS

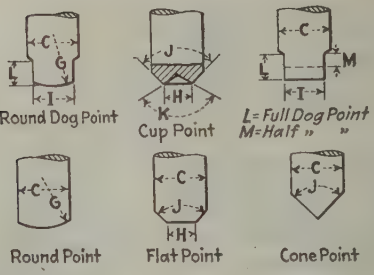
Diam. of Screw		Threads per Inch		
		U.S.S.	S.A.E.	Whitworth
1/4	0.250	20	28	20
5/16	0.31	18	24	18
3/8	0.375	16	24	16
7/16	.....	14	20	14
1/2	0.500	13	20	12
9/16	.....	12	18	12
5/8	0.625	11	18	11
11/16	.....	11	16	11
3/4	0.75	10	16	10
13/16	.....	10		10
7/8	0.875	9	14	9
15/16	.....	9		9
1	1.000	8	14	8
1 1/8	1.125	7	12	7
1 1/4	1.25	7	12	7
1 3/8	1.375	6	12	6
1 1/2	1.50	6	12	6

ALLEN SOCKET-HEAD CAP SCREWS

A = diameter of head.
B = oval head length of side.
C = length of flat head.
D = diameter of screws.
H = size of hex. hole.

Screws 4 inches long and over are threaded 1/2 the length.
Under 4 inches long 3/4 way.

Diam. of Screw *D*	*A*	*B*	*C*	*H*
1/4	3/8	15/64	1/4	1/16
5/16	7/16	9/32	5/16	7/64
3/8	1/2	21/64	3/8	1/8
7/16	9/16	3/8	7/16	9/64
1/2	5/8	27/64	1/2	5/32
9/16	11/16	15/32	9/16	11/64
5/8	3/4	33/64	5/8	3/16
3/4	7/8	39/64	3/4	7/32
7/8	1	45/64	7/8	1/4
1	1 1/8	51/64	1	9/32
1 1/8	1 1/4	57/64	1 1/8	5/16
1 1/4	1 3/8	63/64	1 1/4	11/32
1 3/8	1 1/2	1 1/64	1 3/8	3/8
1 1/2	1 5/8	1 7/64	1 1/2	13/32



DIMENSIONS OF ALLEN HOLLOW SET SCREWS—STANDARD POINTS

(Dog Points—When the length of dog equals half the total length of screw, half dog points furnished)

(Dimensions in Inches)

Diameter of Screw		G	H	I	J	K	L	M
1/4	0.250	0.250	1/8	0.163	90°	118°	1/8	1/16
5/16	0.312	0.312	5/32	0.215	90°	118°	5/32	1/16
3/8	0.375	0.375	3/16	0.265	90°	118°	3/16	3/32
7/16	0.437	0.437	7/32	0.314	90°	118°	7/32	1/16
1/2	0.500	0.500	1/4	0.355	90°	118°	1/4	1/8
9/16	0.562	0.562	9/32	0.408	90°	118°	9/32	1/16
5/8	0.625	0.625	11/32	0.461	90°	118°	1/16	3/32
11/16	0.687	0.687	11/32	0.467	90°	118°	11/32	1/16
3/4	0.750	0.750	1/16	0.567	90°	118°	3/8	1/16
13/16	0.812	0.812	1/16	0.639	90°	118°	13/32	1/16
7/8	0.875	0.875	1/2	0.682	90°	118°	7/16	1/32
15/16	0.937	0.937	1/2	0.745	90°	118°	15/32	1/32
1	1.000	1.000	9/16	0.783	90°	118°	1/2	1/4
1 1/8	1.125	1.125	5/8	0.877	90°	118°	9/16	1/32
1 1/4	1.250	1.250	11/16	1.000	90°	118°	5/8	1/16
1 3/8	1.375	1.375	3/4	1.086	90°	118°	11/16	1/32
1 1/2	1.500	1.500	13/16	1.211	90°	118°	3/4	1/16

AMERICAN SCREW COMPANY, STANDARD THREADS PER INCH

No.	2	3	4	5	6	7	8	9	10	12
Threads per Inch	48 **56** 64	**48** 56	32, 32 **36, 40**		30 **32** 36	30 32	30 **32** 36	24, 24, 30, 30 32, **32**		20 **24**

No.	14	16	18	20	22	24	26	28	30
Threads per Inch	18 **20** 24	16, 16 **18, 18** 20, 20		16, 16 **18, 18**		14 **16** 18	14, 16		

Heavy face indicates threads used the most.

INSTRUMENT SCREWS

PIONEER INSTRUMENT CO.

No.	T.p.i.	Body Diam.	Root Diam.	Tap Drill		Body Drill		Head Diam.	
				No.	Diam.	No.	Diam.	Flat*	Round
0000	160	0.021	0.013	80	0.0135	73	0.024	0.050	
000	120	0.034	0.023	73	0.024	63	0.037	0.060	
00	96	0.047	0.033	66	0.033	55	0.052	0.070	
0	80	0.060	0.0438	56	0.0465	52	0.0635	0.089	
1	72	0.073	0.055	53	0.0595	47	0.0785	0.111	
2	64	0.086	0.0657	50	0.070	42	0.0935	0.164	0.154
3	56	0.099	0.0758	46	0.081	37	0.104	0.190	0.178
4	48	0.112	0.0849	43	0.089	31	0.120	0.216	0.202
6	40	0.138	0.1055	33	0.113	27	0.144	0.268	0.250
8	36	0.164	0.1279	28	0.1405	18	0.1695	0.320	0.298
10	32	0.190	0.1494	20	0.161	9	0.196	0.372	0.346

* Fillister heads on sizes 0000 to 1 inclusive. These are special and can be used in place of either flat or round heads.

FRACTIONAL SIZE SCREW—S. A. E. AND FINE THREADS

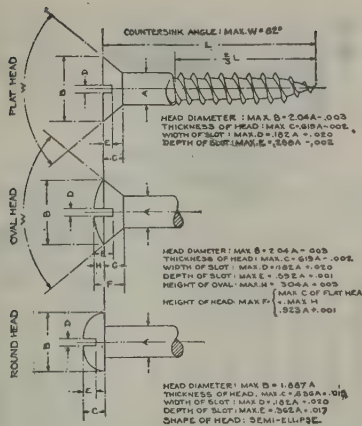
PIONEER INSTRUMENT CO.

Size	Clearance Drill	S. A. E.			Fine*		
		T.p.i.	Root	Tap *D*	T.p.i.	Root	Tap D
1/4	17/64	28	0.204	13/64	32	0.209	13/64
5/16	21/64	24	0.258	17/64	32	0.271	17/64
3/8	25/64	24	0.321	21/64	27	0.327	21/64
7/16	29/64	20	0.372	3/8	27	0.389	25/64
1/2	33/64	20	0.435	29/64	27	0.452	29/64
9/16	37/64	18	0.489	1/2	27	0.513	33/64
5/8	41/64	18	0.553	37/64	27	0.577	37/64
11/16	45/64	16	0.606	41/64			
3/4	49/64	16	0.669	45/64	27	0.702	45/64
7/8	57/64	14	0.782	49/64	27	0.827	49/64
Spark plugs and		18	0.803	13/16	tachometer connections		
1	1 1/32	14	0.907	29/32	27	0.952	61/64

* Fine-thread taps and dies are stocked by some makers.

STANDARD WOOD SCREWS

This standard is the result of cooperation between screw manufacturers and the Bureau of Standards. The increment between sizes is now 0.013 inch instead of 0.013165 inch as formerly. Several sizes have been omitted, the total number of sizes and lengths being reduced from 555 to 291. Gimlet points are standard, cone and diamond points are special. Length of screws is measured from the largest diameter of bearing surface of head to the point. Screws are threaded approximately two-thirds of their length. Diameter is measured under the head. Tolerance on diameter is from 0.004 inch plus to 0.007 inch minus. A 10 per cent. variation in threads per inch is permitted. The angle of cone and flat heads is 82 degrees maximum.



National Wood Screw Standard, Size Numbers, Diameters and Pitches

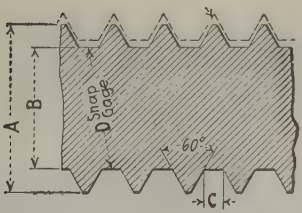
Number of Screw	Threads per Inch	Diameter in Inches					
		Basic	Maximum	Minimum	Basic	Maximum	Minimum
1	2	3	4	5	6	7	8
0	32	0.060	0.064	0.053	1.5	1.6	1.3
1	28	0.073	0.077	0.066	1.9	2.0	1.7
2	26	0.086	0.090	0.079	2.2	2.3	2.0
3	24	0.099	0.103	0.092	2.5	2.6	2.3
4	22	0.112	0.116	0.105	2.8	2.9	2.6
5	20	0.125	0.129	0.118	3.2	3.3	3.0
6	18	0.138	0.142	0.131	3.5	3.6	3.3
7	16	0.151	0.155	0.144	3.8	3.9	3.6
8	15	0.164	0.168	0.157	4.2	4.3	4.0
9	14	0.177	0.181	0.170	4.5	4.6	4.3
10	13	0.190	0.194	0.183	4.8	4.9	4.6
11	12	0.203	0.207	0.196	5.2	5.3	5.0
12	11	0.216	0.220	0.209	5.5	5.6	5.3
14	10	0.242	0.246	0.235	6.1	6.2	5.9
16	9	0.268	0.272	0.261	6.8	6.9	6.6
18	8	0.294	0.298	0.287	7.5	7.6	7.3
20	8	0.320	0.324	0.313	8.1	8.2	7.9
24	7	0.372	0.376	0.365	9.4	9.5	9.2



Coach Screws
(Dimensions in Inches)

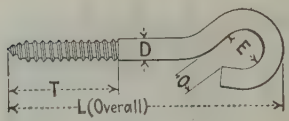
Nom. Diam.	*W*	*H*	*R*	Threads per Inch	Threads per Inch on Pt.	Longest Pointed	Shortest Pointed
$\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	10	$8\frac{1}{2}$	$10\frac{1}{2}$	1
$\frac{5}{16}$	$\frac{15}{32}$	$\frac{15}{64}$	$\frac{5}{32}$	9	$7\frac{1}{2}$	$10\frac{1}{2}$	$1\frac{1}{2}$
$\frac{3}{8}$	$\frac{9}{16}$	$\frac{9}{32}$	1	7	$6\frac{1}{2}$	$10\frac{1}{2}$	$1\frac{1}{2}$
$\frac{7}{16}$	$\frac{21}{32}$	$\frac{21}{64}$	1	7	$6\frac{1}{2}$	$10\frac{1}{2}$	$1\frac{1}{2}$
$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{8}$	$1\frac{1}{4}$	6	$5\frac{1}{2}$	17	$1\frac{1}{2}$
$\frac{9}{16}$	$\frac{27}{32}$	$\frac{27}{64}$	$1\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{1}{2}$	17	$1\frac{3}{4}$
$\frac{5}{8}$	$\frac{15}{16}$	$\frac{15}{32}$	$1\frac{1}{2}$	5	$4\frac{1}{2}$	17	2
$\frac{3}{4}$	$1\frac{1}{16}$	$\frac{1}{2}$	2	$4\frac{1}{2}$	3.9	17	$2\frac{1}{2}$
$\frac{7}{8}$	$1\frac{3}{16}$	$\frac{21}{32}$	*	4	$3\frac{1}{2}$	17	$3\frac{1}{2}$
1	$1\frac{1}{2}$	$\frac{3}{4}$	*	$3\frac{1}{2}$	3	17	$4\frac{1}{2}$

* Crown same as square-head machine bolt. Length of thread varies from about $\frac{1}{4}$, the length on short screws, to $\frac{1}{2}$, the length on long bolts (Buffalo Bolt Co.).



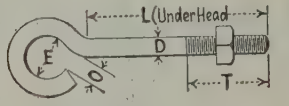
COACH SCREW THREADS
(Dimensions in Inches)

Nom. Diam.	Threads per Inch	A		B	C	D
		Min.	Max.			
$\frac{1}{4}$	10	0.233	0.236	0.185	0.0500	0.191
$\frac{5}{16}$	9	0.294	0.298	0.231	0.0502	0.250
$\frac{3}{8}$	7	0.356	0.360	0.278	0.0690	0.286
$\frac{7}{16}$	7	0.418	0.423	0.324	0.0594	0.333
$\frac{1}{2}$	6	0.479	0.484	0.370	0.0702	0.379
$\frac{9}{16}$	$5\frac{1}{2}$	0.539	0.554	0.416	0.0756	0.426
$\frac{5}{8}$	5	0.601	0.616	0.463	0.0815	0.475
$\frac{3}{4}$	$4\frac{1}{2}$	0.724	0.739	0.555	0.0820	0.566
$\frac{7}{8}$	4	0.849	0.864	0.647	0.0875	0.658
1	$3\frac{1}{2}$	0.974	0.989	0.740	0.0998	0.754



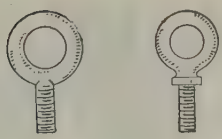
CEILING HOOKS
(Dimensions in Inches)

Trade Size	Diameter *D*	Length *L*	Length Threaded *T*	Diameter of Eye *E*	Width of Opening *O*
$\frac{1}{4} \times 3$	$\frac{1}{4}$	3	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{16}$
$\frac{1}{4} \times 3\frac{1}{2}$	$\frac{1}{4}$	$3\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{16}$
$\frac{5}{16} \times 3$	$\frac{5}{16}$	3	1	$\frac{3}{4}$	$\frac{11}{32}$
$\frac{5}{16} \times 3\frac{1}{2}$	$\frac{5}{16}$	$3\frac{1}{2}$	$1\frac{3}{4}$	$\frac{3}{4}$	$\frac{11}{32}$
$\frac{5}{16} \times 4$	$\frac{5}{16}$	4	$1\frac{3}{4}$	$\frac{3}{4}$	$\frac{11}{32}$
$\frac{3}{8} \times 4\frac{1}{2}$	$\frac{3}{8}$	$4\frac{1}{2}$	$2\frac{1}{4}$	1	$\frac{11}{32}$



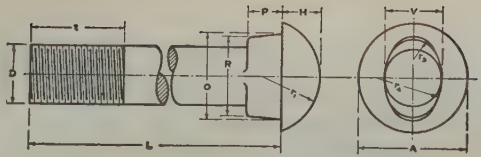
OPEN-EYE EYE BOLTS
(Dimensions in Inches)

Trade Size	Diameter *D*	Length *L*	Length Threaded *T*	Diameter of Eye *E*	Width of Opening *O*
$\frac{1}{4} \times 1\frac{1}{2}$	$\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{9}{64}$
$\frac{1}{4} \times 2$	$\frac{1}{4}$	2	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{9}{64}$
$\frac{1}{4} \times 2\frac{1}{2}$	$\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{9}{64}$
$\frac{1}{4} \times 3$	$\frac{1}{4}$	3	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{9}{64}$
$\frac{1}{4} \times 3\frac{1}{2}$	$\frac{1}{4}$	$3\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{9}{64}$
$\frac{1}{4} \times 4$	$\frac{1}{4}$	4	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{9}{64}$
$\frac{5}{16} \times 1\frac{1}{2}$	$\frac{5}{16}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{5}{16}$
$\frac{5}{16} \times 2\frac{1}{2}$	$\frac{5}{16}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{16}$
$\frac{5}{16} \times 3$	$\frac{5}{16}$	3	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{16}$
$\frac{5}{16} \times 3\frac{1}{2}$	$\frac{5}{16}$	$3\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{16}$
$\times 1\frac{1}{2}$	$\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{11}{32}$
$\times 2\frac{1}{2}$	$\frac{3}{8}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{11}{32}$
$\times 3$	$\frac{3}{8}$	3	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{11}{32}$
$\times 3\frac{1}{2}$	$\frac{3}{8}$	$3\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{11}{32}$



DIMENSIONS OF WILLIAMS "VULCAN" PLAIN AND SHOULDER EYE BOLTS

PLAIN							SHOULDER				
Shank			Diameter Eye		Capacity, Net Tons			Shank			Diameter Eye	
Diameter	Standard Length under Eye	Maximum Length in Stock	Inside	Outside	Safe Working Load	Average Load at Elastic Limit	Approximate Breaking Strain	Diameter	Standard Length under Shoulder	Maximum Length in Stock	Inside	Outside
$\frac{3}{8}$	$1\frac{1}{2}$	$4\frac{1}{2}$	1	$1\frac{21}{32}$	0.7	1.4	3	$\frac{1}{4}$	1	3	$\frac{3}{4}$	$1\frac{3}{16}$
$\frac{7}{16}$	$1\frac{3}{4}$	$4\frac{1}{2}$	$1\frac{7}{32}$	$1\frac{23}{32}$	1	2	4	$\frac{5}{16}$	$1\frac{1}{4}$	4	$\frac{7}{8}$	$1\frac{5}{16}$
$\frac{1}{2}$	$1\frac{1}{4}$	$4\frac{1}{2}$	$1\frac{9}{16}$	$2\frac{1}{16}$	1.3	2.5	5	$\frac{3}{8}$	$1\frac{1}{2}$	$4\frac{1}{2}$	1	$1\frac{1}{4}$
$\frac{9}{16}$	$1\frac{3}{8}$	$4\frac{1}{2}$	$1\frac{1}{32}$	$2\frac{3}{32}$	1.5	3	6	$\frac{7}{16}$	$1\frac{3}{4}$	$4\frac{1}{2}$	$1\frac{3}{32}$	$1\frac{3}{32}$
$\frac{5}{8}$	$1\frac{3}{8}$	$4\frac{1}{2}$	$1\frac{3}{8}$	$2\frac{1}{2}$	2	4	8	$\frac{1}{2}$	$1\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{3}{16}$	$2\frac{1}{16}$
$\frac{3}{4}$	2	5	$1\frac{1}{2}$	$2\frac{13}{16}$	3	6	12	$\frac{9}{16}$	$1\frac{3}{4}$	$4\frac{1}{2}$	$1\frac{3}{32}$	$2\frac{3}{32}$
$\frac{7}{8}$	$2\frac{1}{4}$	5	$1\frac{11}{16}$	$3\frac{1}{16}$	3.5	7	16	$\frac{5}{8}$	$1\frac{3}{4}$	$4\frac{1}{2}$	$1\frac{3}{8}$	$2\frac{3}{8}$
1	$2\frac{1}{2}$	5	$1\frac{13}{16}$	$3\frac{5}{16}$	4	8	20	$\frac{3}{4}$	2	5	$1\frac{1}{2}$	$2\frac{11}{16}$
$1\frac{1}{8}$	$2\frac{3}{4}$	5	2	4	5	10	23	$\frac{7}{8}$	$2\frac{1}{2}$	5	$1\frac{11}{16}$	$3\frac{1}{4}$
$1\frac{1}{4}$	3	6	$2\frac{3}{16}$	$4\frac{7}{16}$	7.5	15	33	1	$2\frac{1}{2}$	5	$1\frac{13}{16}$	$3\frac{5}{16}$
$1\frac{3}{8}$	$3\frac{1}{2}$	6	$2\frac{1}{2}$	$5\frac{5}{16}$	9	18	42	$1\frac{1}{8}$	$2\frac{1}{2}$	5	2	4
$1\frac{1}{2}$	$3\frac{3}{4}$	6	$2\frac{7}{8}$	$6\frac{1}{16}$	11	21	53	$1\frac{1}{4}$	3	6	$2\frac{3}{16}$	$4\frac{7}{16}$
2	4	6	$3\frac{1}{2}$	$6\frac{7}{8}$	13	25	68	$1\frac{1}{2}$	$3\frac{1}{2}$	6	$2\frac{1}{2}$	$5\frac{1}{16}$
$2\frac{1}{2}$	5	6	4	$8\frac{9}{16}$	16	32	85	$1\frac{3}{4}$	$3\frac{1}{2}$	6	$2\frac{7}{8}$	$6\frac{1}{16}$
								2	4	6	$3\frac{1}{4}$	$6\frac{7}{8}$



TRACK BOLTS AND NUTS

Elliptic Neck Track Bolts

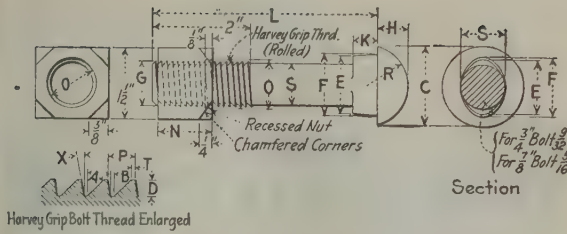
(Dimensions in Inches)

D	Diameter of Thread		A	H	r_1	O	R	P	r_3	r_4	V	L	l	Threads per Inch
Nominal Diameter over Thread	Maximum Major	Minimum Major	Head			Head						Length under Head	Thread Length	
$\frac{3}{4}$	0.7500	0.7316	$1\frac{1}{4}$	$\frac{15}{32}$	$\frac{21}{32}$	$\frac{63}{64}$	$\frac{41}{64}$	$\frac{7}{16}$	$\frac{9}{32}$	$\frac{41}{64}$	This dimension shall be the same as the body diameter of the bolt.	Length as per order—Standard lengths 3 to 6 in. by steps of $\frac{1}{4}$ and 6 in. to 10 in. by steps of $\frac{1}{2}$ in.	$1\frac{3}{4}$	10
$\frac{13}{16}$	0.8125*	.....	$1\frac{11}{32}$	$\frac{33}{64}$	$\frac{11}{16}$	$1\frac{1}{16}$	$\frac{43}{64}$	$\frac{29}{64}$	$\frac{5}{16}$	$\frac{43}{64}$			$1\frac{3}{4}$	10
$\frac{7}{8}$	0.8750	0.8550	$1\frac{7}{16}$	$\frac{9}{16}$	$\frac{47}{64}$	$1\frac{3}{64}$	$\frac{45}{64}$	$\frac{15}{32}$	$\frac{5}{16}$	$\frac{45}{64}$			2	9
$\frac{15}{16}$	0.9375*	.....	$1\frac{17}{32}$	$\frac{19}{32}$	$\frac{25}{32}$	$1\frac{5}{64}$	$\frac{47}{64}$	$\frac{31}{64}$	$\frac{11}{32}$	$\frac{47}{64}$			2	9
1	1.0000	0.9778	$1\frac{5}{8}$	$\frac{21}{32}$	$\frac{13}{16}$	$1\frac{1}{8}$	$\frac{49}{64}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{49}{64}$			$2\frac{1}{4}$	8
$1\frac{1}{8}$	1.1250	1.1002	$1\frac{13}{16}$	$\frac{3}{4}$	$\frac{29}{32}$	$1\frac{5}{32}$	$\frac{51}{64}$	$\frac{17}{32}$	$\frac{13}{32}$	$\frac{51}{64}$			$2\frac{1}{4}$	7
$1\frac{1}{4}$	1.2500	1.2252	2	$\frac{27}{32}$	$1\frac{1}{64}$	$1\frac{1}{8}$	$\frac{53}{64}$	$\frac{9}{16}$	$\frac{7}{16}$	$1\frac{1}{16}$			$2\frac{1}{2}$	7

* Special thread sizes for track bolts.

Tolerances:—Length $L \pm \frac{1}{8}$ inch; neck (V, O and R) $\pm \frac{1}{32}$ inch; head (A and H) $\pm \frac{1}{16}$ inch. Length of thread l plus and minus one thread.

Note.—The threads on track bolts should be either American Standard or *Harvey Grip* thread. They may be formed by cutting, drawing or rolling.



HARVEY GRIP BOLT THREAD ENLARGED

Size of bolt	Dimensions of thread					
	A	X	P	D	B	T
3/4"	45°	Max. 10°	.1000"	Min. .065"	.0118"	.0118"
7/8"	45°	Max. 10°	.1111"	Min. .072"	.0132"	.0132"

Weight of rail	Dimensions											Threads per inch
	S	L	C	H	F	G	K	N	N	O	R	
	3/4"		1 1/8"	1 7/32"	1 3/32"	1 1/16"	1 13/32"	7/16"	1"	7/8"	1 3/64"	10
	7/8"		1 1/4"	1 1/4"	1 5/16"	1 3/32"	1 1/2"	1/2"	1 1/8"	1"	3/4"	9
	1"		1 1/2"	1 3/8"	1 1/8"	1 3/32"	1 11/16"	1/2"	1 1/8"	1"	3/4"	9



Plain Washers
U. S. Standard
(Dimensions in Inches)

Size of Bolt	Size of Hole	Outside Diameter	Thickness Wire Gage No.	Weight per 1,000, in Pounds
1/16	1/4	9/16	18 (5/64)	2.53
1/4	5/16	3/4	16 (1/16)	6.40
5/16	3/8	7/8	16 (1/16)	8.80
3/8	7/16	1	14 (5/64)	14.7
7/16	1/2	1 1/4	14 (5/64)	21
1/2	9/16	1 3/8	12 (3/32)	38.4
9/16	5/8	1 1/2	12 (3/32)	44.4
5/8	11/16	1 3/4	10 (1/8)	77
3/4	13/16	2	10 (1/8)	111
7/8	15/16	2 1/4	9 (5/32)	153
1	1 1/16	2 1/2	9 (5/32)	176
1 1/8	1 1/4	2 3/4	9 (5/32)	
1 1/4	1 3/8	3	9 (5/32)	
1 3/8	1 1/2	3 1/4	8 (11/64)	
1 1/2	1 5/8	3 1/2	8 (11/64)	
1 5/8	1 3/4	3 3/4	8 (11/64)	
1 3/4	1 7/8	4	8 (11/64)	
1 7/8	2	4 1/4	8 (11/64)	
2	2 1/4	4 1/2	8 (11/64)	
2 1/4	2 3/4	4 3/4	6 (7/32)	
2 1/2	2 3/4	5	5 (7/32)	

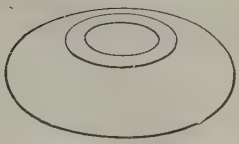
Plain Washers
S. A. E. Standard
(Dimensions in Inches)

Size of Bolt	Size of Hole	Outside Diameter	Thickness Wire Gage No.
6	9/64	3/8	20 (1/32)
8	11/64	7/16	20 (1/32)
10	13/64	1/2	18 (5/64)
1/4	17/64	5/8	16 (1/16)
5/16	21/64	11/16	16 (1/16)
3/8	25/64	13/16	16 (1/16)
7/16	29/64	7/8	14 (5/64)
1/2	33/64	1 1/16	14 (5/64)
9/16	37/64	1 1/8	14 (5/64)
5/8	41/64	1 1/16	12 (3/32)
3/4	49/64	1 1/2	12 (3/32)
7/8	57/64	1 3/4	10 (1/8)

Narrow-gage Washers
(Dimensions in Inches)

1/4	5/16	3/4	16 (1/16)
5/16	3/8	7/8	16 (1/16)
3/8	7/16	1	16 (1/16)
7/16	9/16	1 1/4	14 (5/64)
1/2	5/8	1 1/2	12 (3/32)
9/16	11/16	1 3/4	12 (3/32)
5/8	13/16	1 3/4	10 (1/8)
3/4	15/16	1 3/4	10 (1/8)
7/8	1 1/16	2	9 (5/32)
1	1 1/16	2 1/4	9 (5/32)
1 1/8	1 1/4	2 1/2	9 (5/32)
1 1/4	1 3/8	2 3/4	9 (5/32)
1 3/8	1 1/2	3	8 (11/64)
1 1/2	1 5/8	3 1/2	8 (11/64)

Steel No. 1010. Tolerance plus or minus 0.010.



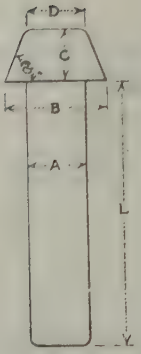
CAST-IRON WASHERS

Size of Bolt	Outside Diameter	Thickness	Size of Bolt	Outside Diameter	Thickness
$\frac{3}{8}$	$1\frac{1}{2}$	$\frac{5}{16}$	$1\frac{1}{8}$	$4\frac{1}{2}$	1
$\frac{1}{2}$	2	$\frac{3}{8}$	$1\frac{1}{4}$	5	$1\frac{1}{8}$
$\frac{5}{8}$	$2\frac{1}{2}$	$\frac{7}{16}$	$1\frac{3}{8}$	$5\frac{1}{2}$	$1\frac{1}{4}$
$\frac{3}{4}$	3	$\frac{1}{2}$	$1\frac{1}{2}$	6	$1\frac{3}{4}$
$\frac{7}{8}$	$3\frac{1}{2}$	$\frac{3}{4}$	$1\frac{3}{4}$	7	$1\frac{1}{2}$
1	4	$\frac{7}{8}$	2	$7\frac{1}{2}$	$1\frac{5}{8}$

RIVETING WASHERS

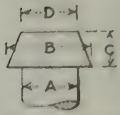
Size of Rivet	Size of Hole	Outside Diameter	Thickness Wire Gage	Size of Rivet	Size of Hole	Outside Diameter	Thickness Wire Gag
7 (.180)	$\frac{3}{16}$	$\frac{1}{2}$	18	$\frac{3}{8}$	$\frac{13}{32}$	$1\frac{1}{4}$	12
6 (.203)	$\frac{7}{32}$	$\frac{9}{16}$	18	$\frac{7}{16}$	$\frac{15}{32}$	1	14
5 (.220)	$\frac{15}{64}$	$\frac{5}{8}$	18	$\frac{7}{16}$	$\frac{1}{2}$	$1\frac{1}{4}$	12
$\frac{1}{4}$	$\frac{17}{64}$	$\frac{5}{8}$	16	$\frac{1}{2}$	$\frac{17}{32}$	$1\frac{1}{8}$	12
$\frac{1}{4}$	$\frac{9}{32}$	$\frac{3}{4}$	16	$\frac{1}{2}$	$\frac{9}{16}$	$1\frac{1}{4}$	12
$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{4}$	14	$\frac{1}{2}$	$\frac{19}{32}$	$1\frac{1}{2}$	11
$\frac{5}{16}$	$\frac{21}{64}$	$\frac{7}{8}$	14	$\frac{5}{8}$	$\frac{21}{32}$	$1\frac{1}{2}$	11
$\frac{3}{8}$	$\frac{13}{32}$	$\frac{7}{8}$	14	$\frac{5}{8}$	$\frac{11}{16}$	$1\frac{3}{4}$	10
$\frac{3}{8}$	$\frac{13}{32}$	1	14				

U. S. Navy Boiler Rivets

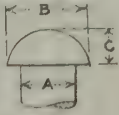


A	B	C	D	Weight of 10 heads	Weight per inch of shank L
½	11/16	7/16	½	.531	.0556
9/16	1	½	9/16	.713	.0704
⅝	1 1/16	9/16	⅝	1.007	.0869
11/16	1 1/8	⅝	11/16	1.372	.1052
¾	1 3/16	11/16	¾	1.551	.1251
13/16	1 5/16	¾	13/16	2.033	.1470
⅞	1 7/16	13/16	⅞	2.258	.1703
15/16	1 ½	⅞	15/16	2.871	.1956
1	1 9/16	15/16	1	3.584	.2225
1 1/16	1 11/16	1	1 1/16	3.910	.2512
1 ⅛	1 13/16	1 1/16	1 ⅛	4.761	.2816
1 3/16	2	1 ⅛	1 3/16	5.170	.3137
1 ¼	2 1/16	1 3/16	1 ¼	6.215	.3477
1 5/16	2 ⅛	1 ¼	1 5/16	7.391	.3833
1 ⅜	2 3/16	1 5/16	1 ⅜	8.490	.4207
1 7/16	2 ¼	1 ⅜	1 7/16	9.941	.4599
1 ½	2 5/16	1 7/16	1 ½	11.507	.5006
1 9/16	2 ⅜	1 ½	1 9/16	13.242	.5433
1 ⅝	2 7/16	1 9/16	1 ⅝	15.146	.5876
1 11/16	3	1 ⅝	1 11/16	17.300	.6336
1 ¾	3 1/16	1 11/16	1 ¾	19.485	.6815

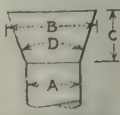
U. S. Navy Hull and Tank Rivet Heads



PAN-HEAD



BUTTON



COUNTERSUNK

Pan-head				Button			Countersunk			
A	B	C	D	A	B	C	A	B	C	D
½	7/16	7/16	½	½	7/16	7/16	½	⅝	⅜	60
⅝	⅝	½	⅝	⅝	⅝	½	⅝	⅝	½	60
¾	11/16	⅝	¾	¾	11/16	⅝	¾	11/16	⅝	60
⅞	1	¾	⅞	⅞	1	¾	⅞	1 1/16	¾	60
1	1 1/16	⅞	1	1	1 1/16	⅞	1	1 1/16	⅞	45
1 1/16	1 1/8	15/16	1 1/16	1 1/16	1 1/8	15/16	1 1/16	1 1/8	1 1/16	45
1 ⅛	1 3/16	1	1 ⅛	1 ⅛	1 3/16	1	1 ⅛	1 3/16	1 1/16	37
1 3/16	1 ¼	1 1/16	1 3/16	1 3/16	1 ¼	1 1/16	1 3/16	1 ¼	1 1/16	37
1 ¼	1 5/16	1 ⅛	1 ¼	1 ¼	1 5/16	1 ⅛	1 ¼	1 5/16	1 ⅛	37
1 5/16	1 11/16	1 3/16	1 5/16	1 5/16	1 11/16	1 3/16	1 5/16	1 11/16	1	37

LENGTH OF ROUND HEAD RIVETS FOR DIFFERENT THICKNESSES OF METAL

To find the required length of a rivet when thickness of metal between rivet heads is given, assuming the rivet hole to be $\frac{1}{16}$ inch larger than the rivet before it is heated, refer to the table below. Grip in inches means thickness of metal between rivet heads.

Grip in Inches.	Diameter in Inches				
	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
	Length in Inches.				
$\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{8}$
$\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{7}{8}$	2	$2\frac{1}{8}$	$2\frac{1}{4}$
$\frac{3}{4}$	$1\frac{3}{4}$	2	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{3}{8}$
$\frac{7}{8}$	$1\frac{7}{8}$	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$
1	2	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$
$1\frac{1}{8}$	$2\frac{1}{8}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$
$1\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$
$1\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	3
$1\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{7}{8}$	3	$3\frac{1}{8}$	$3\frac{1}{4}$
$1\frac{5}{8}$	$2\frac{3}{4}$	3	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{3}{8}$
$1\frac{3}{4}$	$2\frac{7}{8}$	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{1}{2}$
$1\frac{7}{8}$	3	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{5}{8}$
2	$3\frac{1}{8}$	$3\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{3}{4}$
$2\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{3}{4}$	$3\frac{7}{8}$
$2\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{5}{8}$	$3\frac{3}{4}$	$3\frac{7}{8}$	4
$2\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{7}{8}$	4	$4\frac{1}{8}$
$2\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{7}{8}$	4	$4\frac{1}{8}$	$4\frac{1}{4}$
$2\frac{5}{8}$	$3\frac{3}{4}$	4	$4\frac{1}{8}$	$4\frac{1}{4}$	$4\frac{3}{8}$
$2\frac{3}{4}$	$3\frac{7}{8}$	$4\frac{1}{8}$	$4\frac{1}{4}$	$4\frac{3}{8}$	$4\frac{1}{2}$
$2\frac{7}{8}$	4	$4\frac{1}{4}$	$4\frac{3}{8}$	$4\frac{1}{2}$	$4\frac{5}{8}$
3	$4\frac{1}{8}$	$4\frac{1}{2}$	$4\frac{5}{8}$	$4\frac{7}{8}$	$4\frac{7}{8}$
$3\frac{1}{8}$	$4\frac{1}{4}$	$4\frac{5}{8}$	$4\frac{3}{4}$	5	5
$3\frac{1}{4}$	$4\frac{3}{8}$	$4\frac{3}{4}$	$4\frac{7}{8}$	$5\frac{1}{8}$	$5\frac{1}{8}$
$3\frac{3}{8}$	$4\frac{1}{2}$	$4\frac{7}{8}$	5	$5\frac{1}{8}$	$5\frac{1}{4}$
$3\frac{1}{2}$	$4\frac{5}{8}$	5	$5\frac{1}{8}$	$5\frac{1}{4}$	$5\frac{3}{8}$
$3\frac{5}{8}$	$4\frac{3}{4}$	$5\frac{1}{8}$	$5\frac{1}{4}$	$5\frac{3}{8}$	$5\frac{1}{2}$
$3\frac{3}{4}$	$4\frac{7}{8}$	$5\frac{1}{4}$	$5\frac{3}{8}$	$5\frac{1}{2}$	$5\frac{5}{8}$
$3\frac{7}{8}$	5	$5\frac{3}{8}$	$5\frac{1}{2}$	$5\frac{5}{8}$	$5\frac{3}{4}$
4	$5\frac{1}{8}$	$5\frac{1}{2}$	$5\frac{5}{8}$	$5\frac{3}{4}$	$5\frac{7}{8}$
$4\frac{1}{8}$	$5\frac{1}{4}$	$5\frac{5}{8}$	$5\frac{3}{4}$	$5\frac{7}{8}$	6
$4\frac{1}{4}$	$5\frac{3}{8}$	$5\frac{3}{4}$	$5\frac{7}{8}$	6	$6\frac{1}{8}$
$4\frac{3}{8}$	$5\frac{1}{2}$	$5\frac{7}{8}$	6	$6\frac{1}{8}$	$6\frac{1}{4}$
$4\frac{1}{2}$	$5\frac{5}{8}$	6	$6\frac{1}{8}$	$6\frac{1}{4}$	$6\frac{3}{8}$
$4\frac{3}{4}$	$6\frac{1}{8}$	$6\frac{3}{8}$	$6\frac{1}{2}$	$6\frac{3}{8}$	$6\frac{1}{2}$
5	$6\frac{3}{8}$	$6\frac{5}{8}$	$6\frac{3}{4}$	$6\frac{7}{8}$	7

BRITISH ENGINEERING STANDARDS ASSOCIATION

BRITISH STANDARD FINE (B.S.F.) BRIGHT HEXAGON BOLTS, NUTS, SET SCREWS, SPLIT PINS, WASHERS AND STUDS

Sizes $\frac{7}{32}$- to 2-inch diameter

(All Dimensions in Inches) (See Page 486)

Nominal size	A	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$
Minus tolerance in decimals	A	(—0.0035)	(—0.0035)	(—0.0035)	(—0.0035)	(—0.0040)	(—0.0040)	(—0.0400)	(—0.0060)
Number of threads per inch	A	28	26	22	20	18	16	16	14
Width across flats: Minimum	B	0.410	0.440	0.520	0.595	0.705	0.815	0.915	1 002
Maximum	B	0.413	0.445	0.525	0.600	0.710	0.820	0.920	1.010
Approximate width across corners	C	0.48	0.51	0.61	0.69	0.82	0.95	1.06	1.17
B.S.F. BOLTS									
Thickness of bolt head: Minimum	D	0.15	0.18	0.21	0.26	0.32	0.37	0.43	0.48
Maximum	D	0.16	0.19	0.22	0.27	0.33	0 38	0.44	0.49
Minimum length of thread	E	0.437	0.500	0.625	0.750	0.875	1 000	1.125	1 250
When using slotted nut	F	0.14	0.17	0.20	0.27	0.31	0.37	0.41	0.47
When using castle nut	G	0.21	0.24	0.30	0.36	0.45	0.51	0 59	0 66
Drill for split pin hole	L	0.052	0.052	0.070	0.070	0.104	0.104	0.136	0.136
B.S.F. NUTS									
Thickness of nut: Minimum	M	0.161	0.190	0.240	0.302	0.365	0.427	0.490	0.552
Maximum	M	0.171	0.200	0.250	0.312	0.375	0.475	0.500	0.562

B.S.F. LOCK NUTS

Thickness of lock nut:								
Minimum	N	0.104	0.123	0.156	0.198	0.240	0.281	0.323	0.365
Maximum		0.114	0.133	0.166	0.208	0.250	0.291	0.333	0.375

B.S.F. SLOTTED NUTS

Thickness of slotted nut:								
Minimum	M	0.161	0.190	0.240	0.302	0.365	0.427	0.490	0.552
Maximum		0.171	0.200	0.250	0.312	0.375	0.437	0.500	0.562
Face of nut to bottom of slot:								
Minimum	O	0.091	0.120	0.146	0.208	0.225	0.287	0.303	0.365
Maximum		0.101	0.130	0.156	0.218	0.235	0.297	0.313	0.375
Approximate width of slot	S	0.062	0.062	0.084	0.084	0.125	0.125	0.165	0.165
Approximate depth of slot	T	0.070	0.070	0.094	0.094	0.140	0.140	0.187	0.187

B.S.F. CASTLE NUTS

Thickness of hexagon and from face of nut to bottom of slot:								
Minimum	M	0.161	0.190	0.240	0.302	0.365	0.427	0.490	0.552
Maximum		0.171	0.200	0.250	0.312	0.375	0.437	0.500	0.562
Thickness of castle nut:								
Minimum	P	0.231	0.260	0.334	0.396	0.505	0.567	0.677	0.739
Maximum		0.241	0.270	0.344	0.406	0.515	0.577	0.687	0.749
Diameter of castellated portion:								
Minimum	Q	0.395	0.425	0.500	0.575	0.685	0.795	0.895	0.985
Maximum		0.400	0.430	0.510	0.585	0.695	0.805	0.905	0.995
Approximate width of slot	S	0.062	0.062	0.084	0.084	0.125	0.125	0.165	0.165
Approximate depth of slot	T	0.070	0.070	0.094	0.094	0.140	0.140	0.187	0.187
Radius on castellated portion	R	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.07

B.S.F. SPLIT PINS

Diameter and overall length of split pin	U	$\frac{3}{64} \times \frac{5}{8}$	$\frac{3}{64} \times \frac{5}{8}$	$\frac{1}{16} \times \frac{3}{4}$	$\frac{1}{16} \times \frac{3}{4}$	$\frac{3}{32} \times 1$	$\frac{3}{32} \times 1\frac{1}{8}$	$\frac{1}{8} \times 1\frac{1}{4}$	$\frac{1}{8} \times 1\frac{3}{8}$

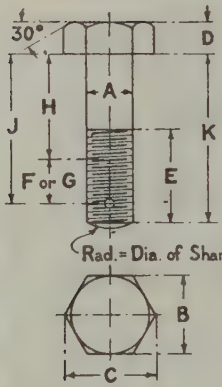


FIG. 1



FIG. 2

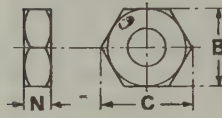


FIG. 3

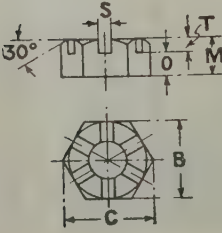


FIG. 4

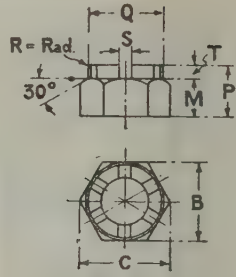


FIG. 5

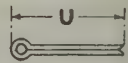


FIG. 6

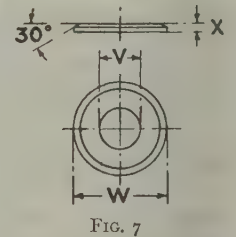


FIG. 7

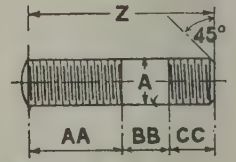


FIG. 8

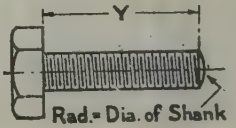


FIG. 9

(*Permission British Engineering Standards Association.*)

Reference cuts for Tables of British Standards

BRITISH STANDARD FINE (B.S.F.) BRIGHT HEXAGON BOLTS, NUTS, SET SCREWS, SPLIT PINS, WASHERS AND STUDS

Sizes $\frac{3}{32}$- to 2-inch diameter
(All dimensions are in inches)

Nominal size Minus tolerance in decimals Number of threads per inch	A	$\frac{3}{32}$ (−0.0035) 28	$\frac{1}{4}$ (−0.0035) 26	$\frac{5}{16}$ (−0.0035) 22	$\frac{3}{8}$ (−0.0035) 20	$\frac{7}{16}$ (−0.0040) 18	$\frac{1}{2}$ (−0.0040) 16	$\frac{9}{16}$ (−0.0040) 16	$\frac{5}{8}$ (−0.0060) 14
B.S.F. WASHERS									
Diameter of hole: Minimum Maximum	V	0.233 0.238	0.265 0.270	0.328 0.333	0.390 0.395	0.453 0.458	0.515 0.520	0.588 0.593	0.651 0.656
Outside diameter: Minimum Maximum	W	0.495 0.500	0.560 0.565	0.620 0.625	0.745 0.750	0.870 0.875	0 995 1.000	0.120 1.125	1.240 1.250
Thickness: Minimum Maximum	X	0.054 0.056	0.054 0.056	0.070 0.072	0.070 0.072	0.090 0.092	0.090 0.092	0.100 0.104	0.112 0.116

B.S.F. STUDS

Overall length of stud	Z	Measured from first thread of long end to flat face of short end.
Long end of stud	AA	Screwed for a length equal to overall length less twice the diameter. Measured from the first to the last full thread.
Plain part of stud	BB	Equal to the diameter of stud.
Short end of stud	CC	Screwed for a length equal to the diameter of stud. Measured from the flat end of the stud to the end of the lead of the thread, *i.e.*, to the point where the thread disappears.

B.S.F. SET SCREWS

Length of set screw	Y	The form and dimensions of the heads and the rounding at the ends of B.S.F. set screws shall be the same as for B.S.F. bolts.

BRITISH ENGINEERING STANDARDS ASSOCIATION

BRITISH STANDARD FINE (B.S.F.) BRIGHT HEXAGON BOLTS, NUTS, SET SCREWS, SPLIT PINS, WASHERS AND STUDS

Sizes $\frac{7}{32}$-to 2-inch diameter
(All Dimensions in Inches)

Nominal size	A	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	2
Minus tolerance in decimals	A	(−0.0060)	(−0.0080)	(−0.0080)	(−0.0080)	(−0.0080)	(−0.0100)	(−0.0100)	(−0.0100
Number of threads per inch	A	12	11	10	9	9	8	7	7
Width across flats: Minimum	B	1.192	1.292	1.468	1.658	1.845	2.200	2.555	2.735
Maximum	B	1.200	1.300	1.480	1.670	1.860	2.220	2.580	2.760
Approximate width across corners	C	1.39	1.50	1.71	1.93	2.15	2.56	2.98	3.19
B.S.F. BOLTS									
Thickness of bolt head: Minimum	D	0.59	0.65	0.76	0.87	0.96	1.18	1.40	1.51
Maximum	D	0.60	0.66	0.77	0.88	0.98	1.20	1.42	1.53
Minimum length of thread	E	1.500	1.750	2.000	2.250	2.500	3.000	3.500	4.000
When using slotted nut	F	0.57	0.64	0.71	0.86	0.96	1.21	1.44	1.52
When using castle nut	G	0.80	0.87	1.02	1.14	1.29	1.54	1.81	1.98
Drill for split pin hole	L	0.166	0.166	0.199	0.199	0.228	0.228	0.261	0.323
B.S.F. NUTS									
Thickness of nut: Minimum	M	0.677	0.740	0.865	0.990	1.105	1.355	1.605	1.730
Maximum	M	0.687	0.750	0.875	1.000	1.125	1.375	1.625	1.750

B.S.F. LOCK NUTS

Thickness of lock nut:								
Minimum	N	0.448	0.490	0.573	0.656	0.730	0.896	0.063	1.146
Maximum	N	0.458	0.500	0.583	0.666	0.750	0.916	1.083	1.166

B.S.F. SLOTTED NUTS

Thickness of slotted nut:								
Minimum	M	0.677	0.740	0.865	0.990	1.105	1.355	1.605	1.730
Maximum	M	0.687	0.750	0.875	1.000	1.125	1.375	1.625	1.750
Face of nut to bottom of slot:								
Minimum	O	0.443	0.506	0.585	0.710	0.777	0.027	1.230	1.262
Maximum	O	0.453	0.516	0.595	0.720	0.797	1.047	1.250	1.282
Approximate width of slot	S	0.208	0.208	0.250	0.250	0.290	0.290	0.333	0.416
Approximate depth of slot	T	0.234	0.234	0.280	0.280	0.328	0.328	0.375	0.468

B.S.F. CASTLE NUTS

Thickness of hexagon and from face of nut to bottom of slot:								
Minimum	M	0.677	0.740	0.865	0.990	1.105	1.355	1.605	1.730
Maximum	M	0.687	0.750	0.875	1.000	1.125	1.375	1.625	1.750
Thickness of castle nut:								
Minimum	P	0.911	0.974	1.145	1.270	1.433	1.683	1.980	2.108
Maximum	P	0.921	0.984	1.155	1.280	1.453	1.703	2.000	2.218
Diameter of castellated portion:								
Minimum	Q	1.165	1.265	1.445	1.635	1.825	2.180	2.535	2.715
Maximum	Q	1.185	1.285	1.465	1.655	1.845	2.200	2.555	2.735
Approximate width of slot	S	0.208	0.208	0.250	0.250	0.290	0.290	0.333	0.416
Approximate depth of slot	T	0.234	0.234	0.280	0.280	0.328	0.328	0.375	0.468
Radius on castellated portion	R	0.08	0.08	0.09	0.09	0.10	0.12	0.14	0.14

B.S.F. SPLIT PINS

Diameter and overall length of split pin	U	$\frac{5}{32} \times 1\frac{1}{2}$	$\frac{5}{32} \times 1\frac{5}{8}$	$\frac{3}{16} \times 2$	$\frac{3}{16} \times 2\frac{1}{8}$	$\frac{7}{32} \times 2\frac{1}{4}$	$\frac{7}{32} \times 2\frac{1}{2}$	$\frac{1}{4} \times 3$	$\frac{5}{16} \times 3\frac{1}{4}$

BRITISH STANDARD FINE (B.S.F.) BRIGHT HEXAGON BOLTS, NUTS, SET SCREWS SPLIT PINS, WASHERS AND STUDS

Sizes $\frac{1}{10}$- to 2-inch Diameter

(All dimensions are in inches)

Nominal size	A	$\frac{1}{10}$	$\frac{1}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	2
Minus tolerance in decimals		(−0 0060)	(−0 0080)	(−0 0080)	(−0.0080)	(−0 0080)	(−0.0100)	(−0 0100)	(−0 0100)
Number of threads per inch		12	11	10	9	9	8	7	7
B.S.F. WASHERS									
Diameter of hole:									
Minimum	V	0 776	0.901	1.026	1.151	1.276	1.526	1 776	2 026
Maximum		0.781	0.906	1 031	1.156	1.281	1.531	1.781	2 031
Outside diameter:									
Minimum	W	1.490	1.615	1.865	2 115	2.360	2.860	3.343	3.593
Maximum		1.500	1.625	1.875	2.125	2.375	2.875	3.375	3 625
Thickness:									
Minimum	X	0.140	0.140	0.156	0.172	0.172	0.188	0.208	0.208
Maximum		0 144	0 144	0.160	0 176	0.176	0.192	0.212	0.212

B.S.F. STUDS		
Overall length of stud	Z	Measured from first thread of long end to flat face of short end.
Long end of stud	AA	Screwed for a length equal to overall length less twice the diameter. Measured from the first to the last full thread.
Plain part of stud	BB	Equal to the diameter of stud.
Short end of stud	CC	Screwed for a length equal to the diameter of stud. Measured from the flat end of the stud to the end of the lead of the thread, *i.e.*, to the point where the thread disappears.
B.S.F. SET SCREWS		
Length of set screw	Y	The form and dimensions of the heads and the rounding at the ends of B.S.F. set screws shall be the same as for B.S.F. bolts.

THE VERNIER AND HOW TO READ IT

This method of measuring or of dividing known distances into very small parts is credited to the invention of Pierre Vernier in 1631. The principle is shown in Figs. 1 to 3 and its application in Figs. 4 and 5. In Figs. 1 and 2 both distances 0 -1 are the same but they are divided into different divisions. Calling 0 — 1 = 1 inch then in Fig. 1 it is clear that moving the lower scale one division will divide the upper one in half. In Fig. 2 the upper scale is divided in half and the lower one in thirds. If the lower scale is moved either way until $\frac{1}{3}$ or $\frac{2}{3}$ comes under the end line, it has moved $\frac{1}{3}$ of an inch

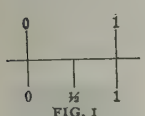


FIG. 1

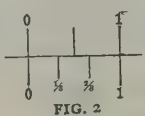


FIG. 2

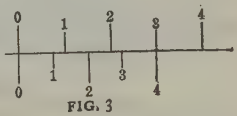


FIG. 3

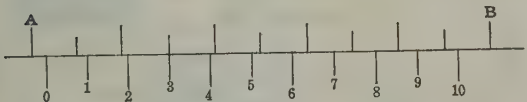


FIG. 4



FIG. 5

Vernier Reading

but if either of these are moved to the center line then it is only moved $\frac{1}{2}$ of this amount or $\frac{1}{6}$.

Figure 3 shows the usual application of the principle except that it is divided in four parts instead of ten. Here both the scales have four parts but on the lower scale the four parts just equal three parts of the upper scale. It is evident that if we move the lower scale so that 0 goes to 1 and 4 goes to 4 that it will be moved $\frac{1}{4}$ the length of the distance 0 — 4 on the upper scale. If this distance was 1 inch, each division on the upper scale equals $\frac{1}{4}$ inch and moving the lower scale so that the line 1 just matches the line next to 0

on the upper scale gives $\frac{1}{4}$ of one of these divisions or $\frac{1}{160}$ of an inch.

Figures 4 and 5 show the usual application in which the lower or vernier scale is divided into 10 parts which equals 9 parts of the upper scale. The same division holds good, however, and when the lower scale is moved so that the first division of the vernier just matches the first line of the scale, it has been moved just one tenth of a division. In Fig. 4 the third lines match so that it has moved $\frac{3}{10}$ and in Fig. 5, $\frac{7}{10}$ of a division. So if A B is one inch then each division is $\frac{1}{10}$ of an inch and each line of the vernier is $\frac{1}{10}$ of that or $\frac{1}{100}$ of an inch.

To find the reading of any vernier, divide one division of the upper or large scale by the number of divisions in the small scale. So if we had a vernier with 16 divisions in each, the large scale being 1 inch long, then the movement of one division is $\frac{1}{16}$ of $\frac{1}{16}$ or $\frac{1}{256}$ of an inch.

READING THE MICROMETER

The commercial micrometer consists of a frame, the anvil or fixed measuring point, the spindle which has a thread cut 40 to the inch on the portion inside the sleeve or barrel and the thimble which

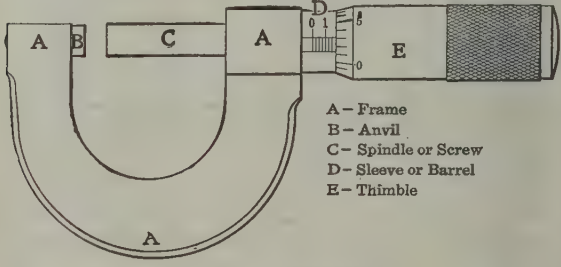


Fig. 6.—Micrometer

goes outside the sleeve and turns the spindle. One turn of the screw moves the spindle $\frac{1}{40}$ or 0.025 of an inch and the marks on the sleeve show the number of turns the screw is moved. Every fourth graduation is marked 1, 2, 3, etc., representing tenths of an inch or as each mark is 0.025 the first four means $0.025 \times 4 = 0.100$, the third means $0.025 \times 4 \times 3 = 0.300$.

The thimble has a beveled edge divided into 25 parts and numbered 0, 5, 10, 15, 20 and to 0 again. Each of these mean $\frac{1}{25}$ of a turn or $\frac{1}{25}$ of $\frac{1}{40} = \frac{1}{1000}$ of an inch. To read, multiply the marks on the barrel by 25 and add the graduations on the edge of the thimble. In Figs. 6 there are 7 marks on the sleeve and 3 on the thimble so we say $7 \times 25 = 175$, plus $3 = 178$ or 0.178.

In shop practice it is common to read them without any multiplying by using mental addition. Beginning at the largest number shown on the sleeve and calling it hundreds and add 25 for each mark, we say in the case shown 100 and 25, 50, 75 and then add the numbers shown on the thimble 3, making 0.178 in all. If it showed 4 and one mark, with the thimble showing 8 marks, the reading would be 400 + 25 + 8 = 433 thousandths or 0.433.

THE TEN-THOUSANDTH MICROMETER

This adds a vernier to the micrometer sleeve or barrel as shown in Fig. 7, which is read the same as any vernier as has been explained. First note the thousandths as in the ordinary micrometer and then look at the line on the sleeve which just matches a line on

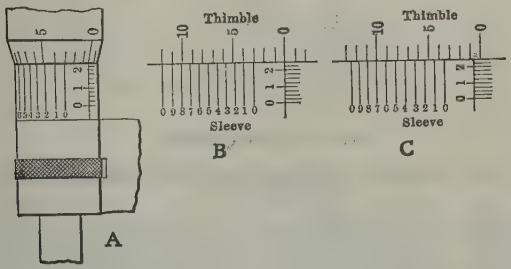


Fig. 7.—Micrometer Graduations

the thimble. If the two zero lines match two lines on the thimble, the measurement is in even thousandths as at *B* which reads 0.250. At *C* the seventh line matches a line on the thimble so the reading is 0.2507 inch.

MEASURING THREE-FLUTED TOOLS WITH THE MICROMETER

The sketch, Fig. 8 on page 494, shows a V-block or gage for measuring three-fluted drills, counterbores, etc.

The angle being 60 degrees, the distances *A*, *B*, and *C* are equal. Consequently to determine the correct diameter of the piece to be measured, apply the gage as indicated in the sketch and deduct one-third of the total measurement.

The use of this gage has a decided advantage over the old way of soldering on a piece of metal opposite a tooth or boring out a ring to fit to.

Using a standard 60-degree triangle for setting and a few different sizes of standard cylindrical plug gages for testing, the V-block may be easily and very accurately made.

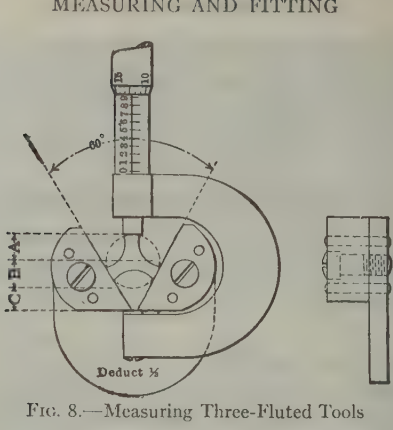


FIG. 8.—Measuring Three-Fluted Tools

USE OF CALIPERS

Side Play of Calipers in Boring Holes Larger than a Piece of Known Diameter

The following is an approximate rule for obtaining the variation in the size of a hole corresponding to a given amount of side play in the calipers. The rule has the merit of extreme simplicity and can be applied equally well to all diameters except the very smallest. In most cases the calculation is so simple that it can be done mentally without having recourse to pencil or paper.

The Calculation

Let A in Fig. 9 = side play of calipers or end measuring rod *in sixteenths of an inch.*

B = dimensions to which calipers are set, or length of measuring rod *in inches.*

C = difference between diameter of hole and length of B *in thousandths of an inch.*

Then $C = \dfrac{A^2}{2B}$, within a very small limit.

Example: A standard end measuring rod, $5\frac{1}{2}$ inches long, has $\frac{3}{8}$ inch of side play in a hole. What is the size of the hole? In this case $A = 6$ and $B = 5\frac{1}{2}$. Apply the above formula:

$$C = \frac{6 \times 6}{11} = \frac{36}{11} = 3.27$$ thousandths of an inch, or 0.00327 inch.

The diameter of the hole, therefore, is $5\frac{1}{2} + 0.00327$ or 5.50327.

The method will be found to be correct within a limit of about 0.0002 inch if the amount of side play is not more than one-eighth of the diameter of the hole for holes up to 6 inches diameter; within 0.0005 inch for holes from 6 inches up to 12 inches; and within 0.001 for holes from 12 inches up to 24 inches.

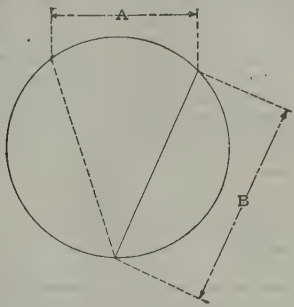


FIG. 9.—Caliper Side Play

Allowing for Running and Driving Fits

This rule has been found to be useful for boring holes of large diameters in which allowances have to be made for running or driving fits, as only a single measuring rod for each nominal size is required. The rods should be of standard length, or a known amount less than standard, the allowances being obtained by varying the amount of side play when boring. The rule is also capable of determining limits, as the maximum and minimum amount of side play allowable can be specified. The measuring rods should be tapered at each end and the points slightly rounded. For accurate work, the body of the rod should be encased in some non-conducting material to nullify the effect of the heat of the hand.

In comparing this method with that described on page 494, it should be remembered that the conditions are reversed—that is to say, the first method is for setting calipers to a given dimension *smaller* than a hole of known diameter, whereas the method now described is for boring a hole a given amount *larger* than a gage of known length.

In measuring the side play it is sufficient to take it to the nearest sixteenth of an inch, and if anything like accuracy is required it should be measured, not guessed at.

INTERCHANGEABLE MANUFACTURE

Standard or Basic Hole Practice

Strict interchangeability consists in making the different parts of a mechanism so uniform in size and contour that each part will fit and properly function in any one of the whole number of mecha-

nisms, no matter when or where it is made. If the quantities being manufactured are large, interchangeable manufacture is economical because it entails a correct system of gaging as well as manufacture. This system does not produce any more scrap or spoiled work than any other—it only indicates by inspection methods which pieces are definitely within or without the prescribed dimensions as represented by the gages.

It is a generally accepted practice in the best shops to have the minimum dimension of the hole or receiving member standard. This is because the means of measuring are better adapted to such standards as plugs, blocks and end measuring rods. Correct standards of this type are easier to produce and as they form a ready means of directly checking the external member of a pair of mating parts, they at once establish the minimum dimension at the logical place. Any external member which will not receive the gage is too small, that is, it is below the standard size.

The mating gage to a plug, block or rod gage (or the other member of a pair of gages) thus directly checks the internal member against being too large or over the standard size. Therefore, standard gages should fix this point of the dimensions of the most difficult fit required in interchangeable manufacture.

In a pair of mating parts that fit and move freely, there is a space or clearance between the mating surfaces. If this space be reduced gradually a condition will ultimately be reached in which there is no space or clearance between the parts, that is, the mating parts are together metal to metal without shake. Then any movement of the parts one within the other will require some force. If this condition of tightness be represented by a horizontal line, which we might call "zero," then this zero line marks the low limit in the dimension of the external member and the high limit of the dimension of the internal member.

Any overlapping of this line by the dimensions of either member of a mating pair tends to produce tightness, and any deviation away from this line without crossing it will tend to produce looseness. This zero line, then, is the logical place to coincide with the standard and the best experience in interchangeable manufacture has verified this and the best shops use it.

In Fig. 10, the zero line *A B* corresponds to the exact standard size and the line *C–D* represents the largest allowable dimension on the tools for external members. The space between the lines *A–B* and *C–D* is the manufacturing tolerance and also the wear limit on these tools. As soon as the tools have worn so that the standard gage will not go in the hole, their use is stopped. It might be asked why not continue their use to, say, 0.001 in. undersize before stopping and so get more wear out of the tool? The obvious answer is because the standard gage will not check it, and hence the gage is of no use.

The tolerance on the tool above the minimum size determines the amount of wear on the tool and not the relation of the minimum size to the standard. If 0.002-in. wear is desired on a tool, then there must be 0.002-in. more looseness when the tool begins to work and this should be above standard, as nothing is gained by

starting it at 0.001-in. above standard and stopping at 0.001 in. under standard.

The line *H–J* represents the largest allowable dimension on the shaft or internal member and the space between this line and the zero line is the minimum allowance, which must never be intentionally encroached upon. It is intended for a predetermined looseness for oil and freedom of fits to prevent seizing.

This space between the zero line and line *H–J* is the difference allowed between the dimensions of the smallest external member and the largest internal member by the designer for the express purpose of establishing the tightest permissible fit.

It is necessary to have a manufacturing tolerance when a large number of these are made and the line *K–L* represents the smallest

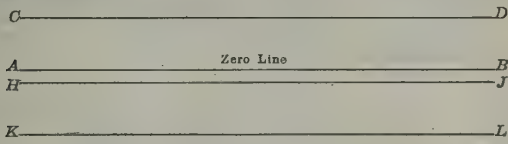


FIG. 10

allowable dimension on the shaft or internal member and the space between the lines *H–J* and *K–L* is the tolerance allowed for manufacturing the internal members.

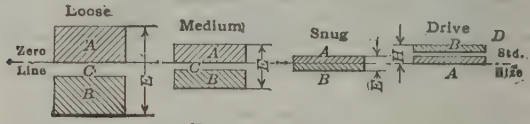
The maximum looseness is represented by the distance between the lines *C–D* and *K–L*. The greatest tightness is represented by the distance between the zero line *A–B* and *H–J*. In this case, the limits for the external member are from standard to *C–D* oversize and the limits for internal member are from *H–J* to *K–L*, both undersize.

The space between the lines *A–B* and *H–J* is commonly called neutral space, indicating that it is not to be encroached upon by the intrusion of the dimensions of either member of a pair of mating parts. In force or shrink fits there is no neutral space but the allowance provides for less than a space, or an imaginary neutral space occupied by part of each member. Figs. 11 and 12 show four common fits. For any class of fit—tight, loose or medium—the standard gage fixes the low limit for the size of the hole or external part. If these parts are made with precision tools, such as reamers or broaches, all these holes can be made with the same tools and carried in stock for all fits. The methods of finishing the shaft or internal members vary so widely that standard tools for this purpose are not commonly carried in stock. The desired kind of fit is secured by making the internal member the required amount undersize. It has been common practice for years to make shafting and cold drawn steel which is used for this purpose about .001 in. or more under the standard size to insure interchangeability in standard holes.

It will be noted that the same minimum plug or "go gage" is used for all holes regardless of fit. This "go gage" is exactly the same as the calibrated standard and is, therefore, checked by it.

Should it be required to either increase or decrease tolerances this gage remains unchanged and the interchangeability is not affected. Increasing the tolerance on the external member increases the size of the "no-go gage," resulting only in more freedom of fit.

The Newall System of gaging, in great favor in England before the standards of the British Engineers Association were adapted, has as its basis a "uniform standard hole," as being the only practicable workable basis for true interchangeability. This should also be extended to screw thread products. Taps are not adjustable—the dies are. The standard threaded plug is easier to produce and



FIGS. 11 AND 12.

calibrate or verify. The threaded ring gages are adjustable and everything points to the logic of extending standard hole practice to screw thread products.

Interchangeability in screw thread fits has also been determined by the National Screw Thread Commission, interchangeability being secured through standardizing the tapped hole. This is done by making the minimum size of all tapped holes basic, regardless of the kind of fit desired. The four classes of thread fits are loose, free, medium and close.

Complete data concerning screw thread fits will be found on pages 34 to 111. These include straight threads and pipe threads of both American and British standards, as well as oil well casings, and hose couplings. Methods of measurement and standards for machine fits in general, are given on the pages that follow.

MEASURING WITH LIGHT WAVES*

While the measurement of gages, tools and parts, with light waves, involves the application of scientific principles of light-wave interference, the method is extremely simple and there are many advantages to be gained from this most accurate measuring facility. Any piece or part that can be measured between the flat measuring faces of a micrometer caliper can be readily measured between the flat surfaces of two optical flats.

Equipment Required

In general, a light-wave-measuring equipment includes the following:

Two optical flats.
One monochromatic light.
One set precision gage block standards.

An optical flat is simply a piece of clear, hard glass which is carefully ground and polished until one surface is perfectly flat. It has no magnifying power, but depends for its usefulness upon the

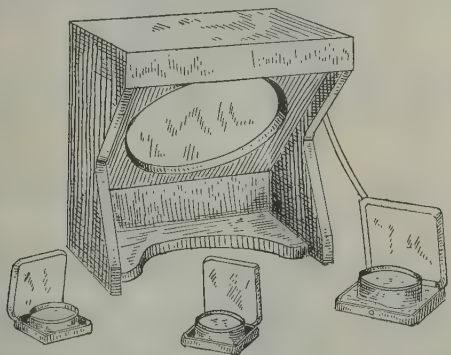


FIG. 13.—Light Wave Measuring Equipment. Comprising two Working Flats, 1 Master Flat and Monochromatic Light

degree of accuracy of the one flat surface. A good working flat should be a true plane within 0.000005 inch (5 millionths), and a master or reference flat should be accurate within 0.0000025 inch ($2\frac{1}{2}$ millionths). An accurate steel flat may be used for a bottom flat with the advantage of lower cost and longer life.

The monochromatic light is a light of one color or wave length. Daylight or white light contains all the colors and wave lengths from about 16 to 26 millionths of an inch. A convenient form of monochromatic light is shown Fig. 13. It is provided with a red

*By H. L. Van Keuren.

selenium glass screen which cuts out all of the colors from an electric lamp except the red, and results in a definite measuring unit of 12½ millionths of an inch per dark band, or 8 bands to the ten-thousandth of an inch. Interference bands seen with daylight are a series of colors similar to the colors of a rainbow, and an approximation of 10 millionths of an inch per band may be used for the measuring unit.

Meaning of the Interference Bands

When an optical flat is placed on a nearly flat lapped or polished reflecting surface, care being taken to exclude moisture, oil or dust, by wiping the surfaces with a clean cloth and then dusting with a camels hair brush, interference bands or alternate light and dark spaces will be seen. Fig. 14 shows the character of these bands,

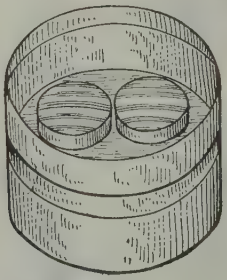


FIG. 14.—Interference Bands on Two Gage Blocks Being Compared for Flatness, Length and Parallelism

which tell the whole story. An examination of the bands seen in Fig. 2, which shows the comparison of two gage blocks, will reveal the following facts:

1. The bands are slightly curved. This indicates that the surfaces of the gage blocks are not perfectly flat. Straight bands indicate a flat surface, curved bands a curved surface. If the bands curve around the "point of contact," or the point where the glass touches the surface being examined, the surface is *convex*. If the curvature of the bands is just the reverse the surface is *concave*.

2. The pronounced light spot and the more clearly defined bands, near the observer (in Fig. 14), indicate the point of contact. As the bands curve around the point of contact the surfaces of the gage blocks are convex.

3. The bands on each gage curve about two-tenths of the distance between successive bands, and the error of flatness is therefore two-tenths of one measuring unit (12½ millionths), or 2½ millionths of an inch.

4. The upper flat is sloping upward toward the rear at the rate of 12½ millionths per dark band. There is therefore a wedge of air between the upper and the gage blocks. At the rear of the right-

hand gage the wedge is 5 times $12\frac{1}{2}$, or 62.5 millionths thick. At the rear of the left-hand gage the wedge is $5\frac{1}{2}$ times $12\frac{1}{2}$ millionths, or 68.75 millionths thick. The gage on the left is, therefore, shorter or smaller than the gage on the right by one-half band, or a little over 6 millionths of an inch.

5. It will be noted also that each band on the left-hand gage occurs about one-half band lower down on the wedge than the bands on the right-hand gage. Thus the comparison of length may be referred to the first band on each gage or to the second or to any successive band.

6. The bands on both gages, although slightly curved, are practically parallel, indicating that the upper surfaces of the two gages as they are wrung on the lower flat are parallel within 1 or 2 millionths of an inch.

Thus with one observation there is obtained the flatness parallelism and length comparison of two gage blocks. Both gages are measured at the same time and at the same temperature. An accuracy of 1 or 2 millionths of an inch is secured and there are no complicated settings or parts to introduce error. The accuracy of the flat may be known by testing them together or, better, by testing three flats in various combinations.

The Principle of the Wedge of Air

The conditions which exist when an optical flat is placed on a gage block, and interference bands made visible, may best be explained by referring to the diagrammatic sketch of Fig. 15, which

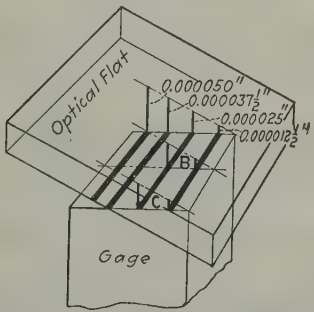


FIG. 15.—Exaggerated Condition Showing Optical Flat Making Angular Contact with Flat Gage Block. Straight Bands Indicate Flat Surface. Bands Locate Vertical Steps of $12\frac{1}{2}$ Millionths of an inch

shows the wedge or angular contact greatly exaggerated, and the surface of the gage block perfectly flat.

The interference bands are caused by the fact that the light reflected from the surface of the gage interferes with the light

reflected from the under surface of the flat. The dark interference bands indicate vertical distances of one-half wave lengths of light. This is strictly true when looking directly down on the surfaces and practically true when viewed at a slight angle.

The first band nearest the point of contact indicates that the vertical distance between the gage and the flat is $12\frac{1}{2}$ millionths of an inch. The second band shows a vertical distance of 25 millionths of an inch, and so on. If the flat is pressed down on the gage the wedge becomes thin and fewer bands or steps of $12\frac{1}{2}$ millionths are present.

If the surfaces are accurately flat, they can be brought together so close that the distance at any point is less than 0.000005 inch and the bands disappear. Thus when a gage block is wrung on a flat, it is in intimate contact, being held on the flat by a very thin film of moisture or grease within 2 or 3 millionths of an inch. It is surprising that, although this film is but a few millionths of an inch thick, it is plainly visible through a glass flat.

Referring again to Fig. 15, the following facts should be observed.

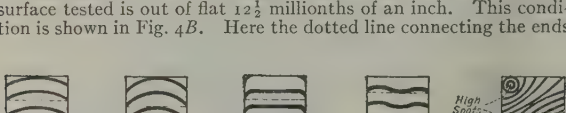
1. Straight bands indicate a flat surface.

2. The number of bands show the steepness of the wedge of air and are units of measurement showing differences of thickness or length between the gage block standard and the piece being measured.

3. The direction of the wedge is at right angles to the direction of the bands.

Amount of Flatness Error

If the bands curve the distance between successive bands, the surface tested is out of flat $12\frac{1}{2}$ millionths of an inch. This condition is shown in Fig. 4*B*. Here the dotted line connecting the ends



a *b* *c* *d* *e*

FIG. 16.—Different Conditions and Degrees of Surface Error. Heavy Lines Indicate Edge in Contact with Flat

a, Convex surface—side edges low 6 millionths. *b*, Convex surface—side edges low 12 millionths. *c*, Nearly flat—side edges low or rounded 6 millionths. *d*, Surface both convex and concave—hollow in center, higher each side of center and lower at side edges. Error 3 millionths. *e*, Note 2 high spots with 12 bands between indicating a valley 6 bands or 75 millionths deep.

of a band just intersects the previous band. In practice, a shadow from a straight edge may be used for the dotted line, but, in general, the flatness error may be estimated to sufficient accuracy. Other conditions of surface error are shown in Fig. 16.

APPLYING THE PRINCIPLE OF THE WEDGE

Measurements of diameter or length are made by wringing a gage block standard on the lower optical flat, and then bringing the upper optical flat in contact with both the gage block and the part being measured. The upper flat must be pressed down until

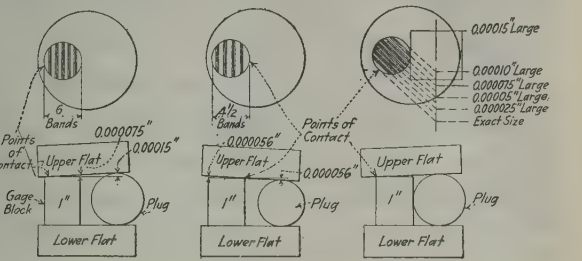


FIG. 17

contact is secured on some point of the gage block and the part being measured. The location of the point of contact on the gage block will depend on the oversize or undersize condition of the part being measured.

It is essential that the location of the point of contact on the gage block be determined. This is readily apparent in daylight

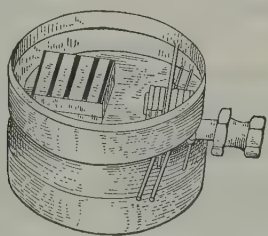


FIG. 18.—Measuring Pitch Diameter of a Thread Gage. A combination of gage block is selected to correspond to the desired measurement over the wires. The flat slopes upward from the left 4 bands across the gage blocks and about 3 bands more to the wires. The pitch diameter is therefore 7 times $12\frac{1}{2}$ millionths or $87\frac{1}{2}$ millionths oversize.

by the absence of color, the grayish surface of the steel gage block being seen.

The gage block, in reality, establishes a parallel reference plane 1 inch—if it be a 1.000-inch gage—above the lower or base surface.

The amount that the part is over or under standard is then easily determined by counting the bands starting from the point of contact on the gage block and continuing to the point of contact on the part being measured.

Fig. 17 shows in a diagrammatic way how the amount oversize or undersize is determined for measuring plug gages. The same principles apply for making other measurements, such as the measurement of pitch diameter of thread gages, as shown in Fig. 18.

Among the uses of light waves should be mentioned the following:

1. Comparing precision gage blocks.

2. Testing flatness of micrometer or measuring-machine contacts, snap gage jaws or other flat gaging surface.

3. Measuring diameters of plug gages, steel balls, rollers, thread gages, thread-measuring wires and accurate cylindrical parts.

4. Measuring thickness of watch hairsprings, thin sheet metal, parchment or like material.

5. Determining coefficient of expansion of metals or other substances.

6. Determining amount of contraction of dental amalgams or cements during the setting process.

TOLERANCES AND ALLOWANCES FOR METAL FITS

Introductory

A Committee of the A. S. M. E. on Plain Limit Gages for General Engineering Work, believing that the terms and definitions used should, as nearly as possible, conform to those in common use, adopted the following fundamentals and definitions.

Fundamentals

Direction of Tolerance on Gages.—The extreme sizes for all plain limit gages shall not exceed the extreme limits of the part to be gaged. All variations in the gages, whatever their cause or purpose, shall bring these gages within these extreme limits. Thus a gage which represents a minimum limit may be larger, but never smaller, than the minimum size specified for the part to be gaged, likewise the gage which represents a maximum limit may be smaller, but never larger, than the maximum size specified for the part to be gaged.

The temperature of 68 degrees Fahr. (20 degrees Cent.) shall be the standard for plain limit gages.

The final result sought by gaging is interchangeable manufacture in some degree. This means that the parts of a mechanism can be assembled without *fitting* one part to another and when assembled the parts will function properly.

Applied to manufactured material, the result sought is sufficient uniformity in size and contour to adapt the material without further fitting to the requirements of the industries. The fundamental principle involved in interchangeable manufacture requires that "a system of standardization and classification of fits shall

establish a clearly defined line at which interference between mating parts begins." Hence,

(*a*) The standard or basic size, as physically represented by a correct standard master gage, represents the line at which this interference begins between mating parts.

(*b*) It is the minimum size of the external members of all mating parts of standardized practice, regardless of the kind of fit.

(*c*) It is the maximum size of internal members of all mating parts where interference begins or that fit metal to metal.*

(*d*) The limits of the component as physically represented by the limit master gages shall not be exceeded as a result either of tolerance or wear of the gages.

(*e*) "Go" gages, or the equivalent verification of all the factors involved in the fit, are necessary to prevent interference of mating parts.

In the case of force fits, "go" gages are necessary to determine the maximum amount of interference between mating parts.

(*f*) "Not go" gages, or the equivalent verification of the determining factor, are necessary to prevent the maximum looseness of mating parts exceeding the limits specified.

In the case of force fits, "not go" gages are necessary to determine the minimum amount of interference between mating parts.

Definitions

Gaging.—A process of measuring manufactured materials to assure the specified uniformity of size and contour required by the industries.

Gage.—A device for determining whether or not one or more of the dimensions of a manufactured part are within specified limits.

(*a*) *Ring Gage.*—One whose inside measuring surfaces are circular in form. The measuring surfaces may be cylindrical or conical.

(*b*) *Plug Gage.*—One whose outside measuring surfaces are arranged to verify the specified uniformity of holes. A plug gage may be straight or tapered and of any cross-sectional shape.

(*c*) *Receiving Gage.*—One whose inside measuring surfaces are arranged to verify the specified uniformity of size and contour of manufactured material.

(*d*) *Indicating Gage.*—One that exhibits visually the variations in the uniformity of dimensions or contour, the amount of the variation being indicated by lever on graduated scale, dial, flush pin, plunger gages, etc.

(*e*) *Snap Gage.*—A fixed gage arranged with inside measuring surfaces for calipering diameters, lengths, thicknesses, etc.

(*f*) *Caliper Gage.*—One which, for internal members, is similar to a snap gage, and for external members, is similar to a plug gage.

Standard.—A physical representation of a form, dimension or size established by law or by general usage and consent.

Standard Sizes.—A series of recognized or accepted sizes corresponding to various subdivisions of a recognized unit of length such

* The condition of (*b*) and (*c*) is represented by a mating pair of correctly fitting standard gages.

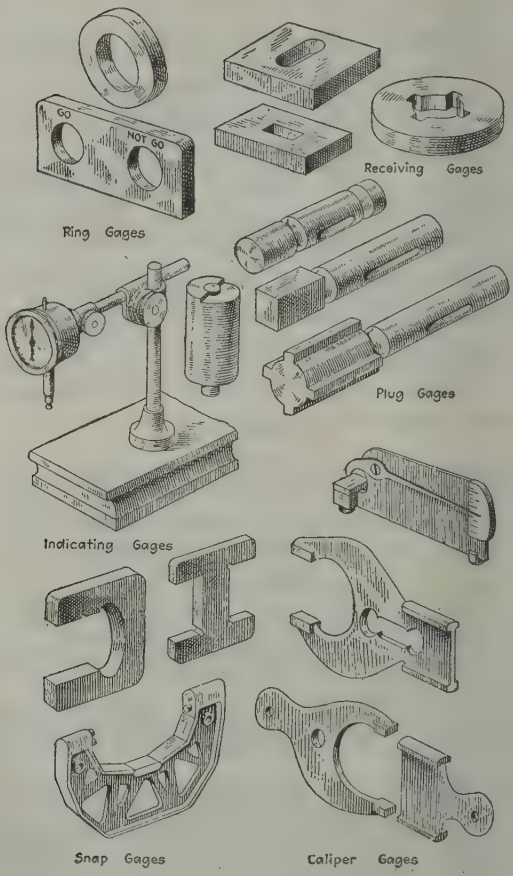


FIG. 19.—Types of gages

as the yard or the meter. These are usually expressed in inches or in millimeters, sometimes by arbitrary numbers or letters.

NOTE.—The industries by common consent have chosen several different series important for interchangeable manufacture. For instance, the common fractions of an inch are commonly called standard sizes, such as $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$ inch, etc.

Nominal Size.—A designation given to the subdivision of the unit of length having no specified limits of accuracy, but indicating a close approximation to a standard size.

Basic Size.—The exact theoretical size from which all limiting variations are made.

Allowance (Neutral Zone.)—An intentional difference in the dimensions of mating parts; or the minimum clearance space which is intended between mating parts. It represents the condition of the tightest permissible fit, or the largest internal member mated with the smallest external member. It is to provide for different classes of fit.

EXAMPLE.—A shaft dimensioned 0.874 inch and a hole dimensioned 0.875 inch represent an allowance of 0.001 inch. The same hole with a shaft dimensioned 0.876 inch represents an allowance of 0.001 inch also; but, as the shaft is larger than the hole, this allowance becomes a negative quantity. (See "Explanatory Notes," page 531.)

Tolerance.—The amount of variation permitted in the size of a part.

NOTE.—In the example under Allowance, the ideal condition and the tightest fit permissible have been given; but in manufacturing large numbers of pieces these sizes could not be produced exactly, so variations must be made that will not prevent their proper functioning but will enable them to be produced. These variations must therefore tend toward greater looseness. Therefore, if a manufacturing tolerance of 0.001 inch is required on each member, they would be dimensioned as follows:

Shaft	0.874 inch + 0.000 inch − 0.001 inch
Hole	0.875 inch + 0.001 inch − 0.000 inch

This defines a condition in which the greatest looseness is 0.003 inch and the greatest tightness gives a clearance of 0.001 inch.

Neutral Zone.—see Allowance.

Limits.—The extreme permissible dimensions of a part.

Master Gage.—One whose gaging dimensions represent as exactly as possible the physical dimensions of the component. It is the gage to which all other gages and all dimensions of manufactured material are finally checked or compared, either by direct check or comparison.

Inspection Gages.—Gages for the use of the manufacturer or purchaser in accepting the product. These gages must not accept any product which the master gages will reject.

TABLE 1.—STANDARD FITS, SUMMARY OF TIGHTEST, LOOSEST AND SELECTED CONDITION FOR ALL CLASSES OF FIT
(All Dimensions in Inches)

Size			Loose Fit (Class 1)		Free Fit (Class 2)		Medium Fit (Class 3)		Snug Fit (Class 4)		Wringing Fit (Class 5)		Tight Fit (Class 6)	Medium Force Fit (Class 7)	Heavy Force and Shrink Fit (Class 8)
			Tightest Fit	Loosest Fit	Tightest Fit	Loosest Fit	Tightest Fit	Loosest Fit	Tightest Fit	Loosest Fit	Tightest Fit	Loosest Fit	Selected Fit	Selected Fit	Selected Fit
From	Up to and Including	Mean	Allowance	Allowance + Tolerances	Allowance	Allowance + Tolerances	Allowance	Allowance + Tolerances	Allowance	Allowance + Tolerances	Allowance	Allowance + Tolerances	Average Interference of metal	Average Interference of metal	Average Interference of metal
			+[1]	+[1]	+[1]	+[1]	+[1]	+[1]		+[1]	−[1]	+[1]	−[2]	−[2]	−[2]
0	$\frac{2}{16}$	$\frac{1}{32}$	0.001	0.003	0.0004	0.0018	0.0002	0.0010	0.0000	0.0005	0.0002	0.0003	0.0000	0.0001	0.0001
$\frac{2}{16}$	$\frac{16}{16}$	$\frac{3}{32}$	0.001	0.005	0.0006	0.0022	0.0004	0.0014	0.0000	0.0007	0.0003	0.0004	0.0001	0.0001	0.0003
$\frac{16}{16}$	$\frac{16}{16}$	$\frac{5}{32}$	0.001	0.005	0.0007	0.0025	0.0005	0.0017	0.0000	0.0007	0.0003	0.0004	0.0001	0.0002	0.0004
$\frac{7}{16}$	$\frac{9}{16}$	$\frac{7}{32}$	0.002	0.006	0.0009	0.0029	0.0006	0.0018	0.0000	0.0008	0.0003	0.0005	0.0001	0.0003	0.0005
$\frac{9}{16}$	$\frac{11}{16}$	$\frac{9}{32}$	0.002	0.006	0.0010	0.0032	0.0007	0.0021	0.0000	0.0008	0.0003	0.0005	0.0002	0.0003	0.0006
$\frac{11}{16}$	$\frac{13}{16}$	$\frac{11}{32}$	0.002	0.006	0.0012	0.0036	0.0007	0.0021	0.0000	0.0009	0.0004	0.0005	0.0002	0.0004	0.0008
$\frac{13}{16}$	$\frac{15}{16}$	$\frac{13}{32}$	0.002	0.006	0.0013	0.0037	0.0008	0.0024	0.0000	0.0010	0.0004	0.0006	0.0002	0.0004	0.0009
$\frac{15}{16}$	$1\frac{1}{16}$	1	0.003	0.009	0.0014	0.0040	0.0009	0.0025	0.0000	0.0010	0.0004	0.0006	0.0003	0.0005	0.0010
$1\frac{1}{16}$	$1\frac{3}{16}$	$1\frac{1}{4}$	0.003	0.009	0.0015	0.0043	0.0010	0.0026	0.0000	0.0010	0.0004	0.0006	0.0003	0.0006	0.0011
$1\frac{3}{16}$	$1\frac{5}{8}$	$1\frac{1}{4}$	0.003	0.009	0.0016	0.0044	0.0010	0.0028	0.0000	0.0010	0.0004	0.0006	0.0003	0.0006	0.0013

1 3/8	1 5/8	1 1/2	0.003	0.009	0.0018	0.0048	0.0012	0.0030	0.0000	0.0012	0.0005	0.0007	0.0004	0.0008	0.0015
1 5/8	1 7/8	1 3/4	0.004	0.010	0.0020	0.0052	0.0013	0.0033	0.0000	0.0012	0.0005	0.0007	0.0004	0.0009	0.0018
1 7/8	2 1/8	2	0.004	0.010	0.0022	0.0054	0.0014	0.0034	0.0000	0.0013	0.0005	0.0008	0.0005	0.0010	0.0020
2 1/8	2 3/8	2 1/4	0.004	0.010	0.0024	0.0058	0.0015	0.0035	0.0000	0.0013	0.0005	0.0008	0.0006	0.0011	0.0023
2 3/8	2 5/8	2 1/2	0.005	0.011	0.0026	0.0062	0.0017	0.0039	0.0000	0.0013	0.0005	0.0008	0.0006	0.0013	0.0025
2 5/8	2 7/8	3	0.005	0.013	0.0029	0.0067	0.0019	0.0043	0.0000	0.0015	0.0006	0.0009	0.0008	0.0015	0.0030
2 7/8	3 1/4	3 1/2	0.006	0.014	0.0032	0.0072	0.0021	0.0045	0.0000	0.0015	0.0006	0.0009	0.0009	0.0018	0.0035
3 1/4	3 3/4	4	0.006	0.014	0.0035	0.0077	0.0023	0.0049	0.0000	0.0016	0.0006	0.0010	0.0010	0.0020	0.0040
3 3/4	4 1/4	4 1/2	0.007	0.015	0.0038	0.0080	0.0025	0.0051	0.0000	0.0017	0.0007	0.0010	0.0011	0.0023	0.0045
4 1/4	4 3/4	5	0.007	0.015	0.0041	0.0085	0.0026	0.0054	0.0000	0.0017	0.0007	0.0010	0.0013	0.0025	0.0050
4 3/4	5 1/4	5 1/2	0.008	0.018	0.0046	0.0094	0.0030	0.0060	0.0000	0.0018	0.0007	0.0011	0.0015	0.0030	0.0060
5 1/4	6 1/4	6	0.009	0.019	0.0051	0.0101	0.0033	0.0063	0.0000	0.0019	0.0008	0.0011	0.0018	0.0035	0.0070
6 1/4	7 1/4	7	0.009	0.019	0.0051	0.0101	0.0033	0.0063	0.0000	0.0019	0.0008	0.0011	0.0018	0.0035	0.0070
7 1/2	8 1/2	8	0.010	0.020	0.0056	0.0108	0.0036	0.0068	0.0000	0.0020	0.0008	0.0012	0.0020	0.0040	0.0080

[1] + denotes clearance or amount of looseness.
[2] Obtained by fitting or selection.

Working Gages.—Gages used by the manufacturer to check the work as it is produced. These gages should not accept any product which the inspection gages will reject.

Classification of Fits

The following classification of fits is recommended·

Loose Fit (Class 1)—Large Allowance.—This fit provides for considerable freedom and embraces certain fits where accuracy is not essential.

EXAMPLES.—Machined fits of agricultural and mining machinery; controlling apparatus for marine work; textile, rubber, candy and bread machinery; general machinery of a similar grade; some ordnance material.

Free Fit (Class 2)—Liberal Allowance.—For running fits with speeds of 600 r.p.m. or over, and journal pressures of 600 pounds per square inch or over.

EXAMPLES.—Dynamos, engines, many machine-tool parts and some automotive parts.

Medium Fit (Class 3)—Medium Allowance.—For running fits under 600 r.p.m. and with journal pressures less than 600 pounds per square inch; also for sliding fits; and the more accurate machine-tool and automotive parts.

Snug Fit (Class 4)—Zero Allowance.—This is the closest fit which can be assembled by hand and necessitates work of considerable precision. It should be used where no perceptible shake is permissible and where moving parts are not intended to move freely under a load.

Wringing Fit (Class 5)—Zero to Negative Allowance.—This is also known as a "tunking fit" and it is practically metal-to-metal. Assembly is usually selective and not interchangeable.

Tight Fit (Class 6)—Slight Negative Allowance.—Light pressure is required to assemble these fits and the parts are more or less permanently assembled, such as the fixed ends of studs for gears, pulleys, rocker arms, etc. These fits are used for drive fits in thin sections or extremely long fits in other sections and also for shrink fits on very light sections. Used in automotive, ordnance and general machine manufacturing.

Medium Force Fit (Class 7)—Negative Allowance.—Considerable pressure is required to assemble these fits and the parts are considered permanently assembled. These fits are used in fastening locomotive wheels, car wheels, armatures of dynamos and motors and crank disks to their axles or shafts. They are also used for shrink fit on medium sections or long fits. These fits are the tightest which are recommended for cast-iron holes or external members, as they stress cast iron to its elastic limit.

Heavy Force and Shrink Fit (Class 8)—Considerable Negative Allowance.—These fits are used for steel holes where the metal can be highly stressed without exceeding its elastic limit. These fits cause excessive stress for cast-iron holes. Shrink fits are used where heavy force fits are impractical, as on locomotive wheel tires, heavy crank disks of large engines, etc.

Standard Fits Applied to Interchangeable Manufacture

Interchangeable Assembly.—Machine shop practices are governed largely by the conditions which must be met. These conditions are many and varied. The standard fits specified in Table 1 can be applied to all practices.

Tables 2 to 5 inclusive show the limiting sizes of mating parts for interchangeable manufacture.

Using the basic hole principle on which this report is based, shaft members made to the specifications of one class of fit may be mated with hole members made to the specifications of another class without destroying interchangeability.

Selective Assembly.—When the functional conditions of mating parts become so exacting that they cannot be maintained with the use of reasonable manufacturing tolerances, a practice known as "selective assembly" is often employed. In selective assembly, attainable manufacturing tolerances are established, then the completed parts are sorted or mated according to size so as to maintain the required functional conditions. The productive processes here are the same as those for interchangeable manufacturing, with the addition of a sorting or mating operation before assembly.

Tables 6 to 9 inclusive show the limiting sizes for the manufacture of mating parts which are to be assembled by selection.

TABLE 2.—LOOSE FIT (CLASS 1)—LARGE ALLOWANCE INTERCHANGEABLE

This fit provides for considerable freedom and embraces certain fits where accuracy is not essential.

(All Dimensions in Inches)

Size			Limits				Tightest Fit	Loosest Fit
			Hole or External Member		Shaft or Internal Member			
From	Up to and Inclusive	Mean	+		−	−	Allowance +*	Allowance + Tolerances +*
0	3/16	1/8	0.001	0.000	0.001	0.002	0.001	0.003
3/16	7/16	5/16	0.002	0.000	0.001	0.003	0.001	0.005
7/16	7/8	5/8	0.002	0.000	0.001	0.003	0.001	0.005
7/16	9/16	1/2	0.002	0.000	0.002	0.004	0.002	0.006
9/16	11/16	5/8	0.002	0.000	0.002	0.004	0.002	0.006
11/16	13/16	3/4	0.002	0.000	0.002	0.004	0.002	0.006
13/16	15/16	7/8	0.002	0.000	0.002	0.004	0.002	0.006
15/16	1 1/16	1	0.003	0.000	0.003	0.006	0.003	0.009
1 1/16	1 3/16	1 1/8	0.003	0.000	0.003	0.006	0.003	0.009
1 3/16	1 5/16	1 1/4	0.003	0.000	0.003	0.006	0.003	0.009
1 5/16	1 7/16	1 3/8	0.003	0.000	0.003	0.006	0.003	0.009
1 7/16	1 9/16	1 1/2	0.003	0.000	0.004	0.007	0.004	0.010
1 9/16	2 1/2	2	0.003	0.000	0.004	0.007	0.004	0.010
2 1/2	2 3/4	2 1/4	0.003	0.000	0.004	0.007	0.004	0.010
2 3/4	2 1/2	2 1/2	0.003	0.000	0.005	0.008	0.005	0.011
2 1/2	3 1/2	3	0.004	0.000	0.005	0.009	0.005	0.013
3 1/2	3 1/2	3 1/2	0.004	0.000	0.006	0.010	0.006	0.014
3 1/2	4 1/2	4	0.004	0.000	0.006	0.010	0.006	0.014
4 1/2	4 3/4	4 1/2	0.004	0.000	0.007	0.011	0.007	0.015
4 1/2	5 1/2	5	0.004	0.000	0.007	0.011	0.007	0.015
5 1/2	6 1/2	6	0.005	0.000	0.008	0.013	0.008	0.018
6 1/2	7 1/2	7	0.005	0.000	0.009	0.014	0.009	0.019
7 1/2	8 1/2	8	0.005	0.000	0.010	0.015	0.010	0.020

*NOTE: + denotes clearance or amount of looseness.



SUMMARY OF DATA

	Hole	Shaft	
Tightest fit	2.125	2.121	0.004 Allowance
Loosest fit	2.128	2.118	0.010 Allowance + Tolerances

FORMULAS

When d = mean size,

Hole tolerance $= 0.0025\sqrt[4]{d}$

Shaft tolerance $= 0.0025\sqrt[3]{d}$

Allowance $= 0.0025\sqrt[3]{d^2}$

TABLE 3.—FREE FIT (CLASS 2)—LIBERAL ALLOWANCE INTERCHANGEABLE

For running fits with speeds of 600 r.p.m. or over, and journal pressures of 600 pounds per square inch or over.

(All Dimensions in Inches)

Size			Limits				Tightest Fit	Loosest Fit
			Hole or External Member		Shaft or Internal Member			
From	Up to and Inclusive	Mean	+		−	−	Allowance +*	Allowance + Tolerances +*
0	3/16	1/8	0.0007	0.0000	0.0004	0.0011	0.0004	0.0018
3/16	1/4	7/32	0.0008	0.0000	0.0006	0.0014	0.0006	0.0022
1/4	7/16	3/8	0.0009	0.0000	0.0007	0.0016	0.0007	0.0025
7/16	9/16	1/2	0.0010	0.0000	0.0009	0.0019	0.0009	0.0029
9/16	11/16	5/8	0.0011	0.0000	0.0010	0.0021	0.0010	0.0032
11/16	13/16	3/4	0.0012	0.0000	0.0012	0.0024	0.0012	0.0036
13/16	15/16	7/8	0.0012	0.0000	0.0013	0.0025	0.0013	0.0037
15/16	1 1/16	1	0.0013	0.0000	0.0014	0.0027	0.0014	0.0040
1 1/16	1 3/16	1 1/8	0.0014	0.0000	0.0015	0.0029	0.0015	0.0043
1 3/16	1 5/16	1 1/4	0.0014	0.0000	0.0016	0.0030	0.0016	0.0044
1 5/16	1 7/16	1 3/8	0.0015	0.0000	0.0018	0.0033	0.0018	0.0048
1 7/16	1 9/16	1 1/2	0.0016	0.0000	0.0020	0.0036	0.0020	0.0052
1 9/16	2	1 3/4	0.0016	0.0000	0.0022	0.0038	0.0022	0.0054
2	2 1/16	2	0.0017	0.0000	0.0024	0.0041	0.0024	0.0058
2 1/16	2 1/8	2 1/8	0.0018	0.0000	0.0026	0.0044	0.0026	0.0062
2 1/8	2 3/16	2 1/4	0.0019	0.0000	0.0029	0.0048	0.0029	0.0067
2 3/16	2 1/4	2 3/8	0.0020	0.0000	0.0032	0.0052	0.0032	0.0072
2 1/4	2 3/8	2 1/2	0.0021	0.0000	0.0035	0.0056	0.0035	0.0077
2 3/8	2 1/2	2 5/8	0.0021	0.0000	0.0038	0.0059	0.0038	0.0080
2 1/2	2 5/8	2 3/4	0.0022	0.0000	0.0041	0.0063	0.0041	0.0085
2 5/8	2 3/4	2 7/8	0.0023	0.0000	0.0043	0.0066	0.0043	0.0089
2 3/4	2 7/8	3	0.0024	0.0000	0.0046	0.0070	0.0046	0.0094
2 7/8	3	3 1/8	0.0025	0.0000	0.0051	0.0076	0.0051	0.0101
3	3 1/8	3 1/4	0.0026	0.0000	0.0056	0.0082	0.0056	0.0108
3 1/8	3 1/4	3 3/8	0.0027	0.0000	0.0061	0.0088	0.0061	0.0115
3 1/4	3 3/8	3 1/2	0.0028	0.0000	0.0066	0.0094	0.0066	0.0122
3 3/8	3 1/2	3 5/8	0.0029	0.0000	0.0071	0.0100	0.0071	0.0129
3 1/2	3 5/8	3 3/4	0.0030	0.0000	0.0076	0.0106	0.0076	0.0136
3 5/8	3 3/4	3 7/8	0.0031	0.0000	0.0081	0.0112	0.0081	0.0143
3 3/4	3 7/8	4	0.0032	0.0000	0.0086	0.0118	0.0086	0.0150
3 7/8	4	4 1/8	0.0033	0.0000	0.0091	0.0124	0.0091	0.0157
4	4 1/8	4 1/4	0.0034	0.0000	0.0096	0.0130	0.0096	0.0164
4 1/8	4 1/4	4 3/8	0.0035	0.0000	0.0101	0.0136	0.0101	0.0171
4 1/4	4 3/8	4 1/2	0.0036	0.0000	0.0106	0.0142	0.0106	0.0178
4 3/8	4 1/2	4 5/8	0.0037	0.0000	0.0111	0.0148	0.0111	0.0185
4 1/2	4 5/8	4 3/4	0.0038	0.0000	0.0116	0.0154	0.0116	0.0192
4 5/8	4 3/4	4 7/8	0.0039	0.0000	0.0121	0.0160	0.0121	0.0199
4 3/4	4 7/8	5	0.0040	0.0000	0.0126	0.0166	0.0126	0.0206
4 7/8	5	5 1/8	0.0041	0.0000	0.0131	0.0172	0.0131	0.0213
5	5 1/8	5 1/4	0.0042	0.0000	0.0136	0.0178	0.0136	0.0220
5 1/8	5 1/4	5 3/8	0.0043	0.0000	0.0141	0.0184	0.0141	0.0227
5 1/4	5 3/8	5 1/2	0.0044	0.0000	0.0146	0.0190	0.0146	0.0234
5 3/8	5 1/2	5 5/8	0.0045	0.0000	0.0151	0.0196	0.0151	0.0241
5 1/2	5 5/8	5 3/4	0.0046	0.0000	0.0156	0.0202	0.0156	0.0248
5 5/8	5 3/4	5 7/8	0.0047	0.0000	0.0161	0.0208	0.0161	0.0255
5 3/4	5 7/8	6	0.0048	0.0000	0.0166	0.0214	0.0166	0.0262
5 7/8	6	6 1/8	0.0049	0.0000	0.0171	0.0220	0.0171	0.0269
6	6 1/8	6 1/4	0.0050	0.0000	0.0176	0.0226	0.0176	0.0276
6 1/8	6 1/4	6 3/8	0.0051	0.0000	0.0181	0.0232	0.0181	0.0283
6 1/4	6 3/8	6 1/2	0.0052	0.0000	0.0186	0.0238	0.0186	0.0290
6 3/8	6 1/2	6 5/8	0.0053	0.0000	0.0191	0.0244	0.0191	0.0297
6 1/2	6 5/8	6 3/4	0.0054	0.0000	0.0196	0.0250	0.0196	0.0304
6 5/8	6 3/4	6 7/8	0.0055	0.0000	0.0201	0.0256	0.0201	0.0311
6 3/4	6 7/8	7	0.0056	0.0000	0.0206	0.0262	0.0206	0.0318
6 7/8	7	7 1/8	0.0057	0.0000	0.0211	0.0268	0.0211	0.0325
7	7 1/8	7 1/4	0.0058	0.0000	0.0216	0.0274	0.0216	0.0332
7 1/8	7 1/4	7 3/8	0.0059	0.0000	0.0221	0.0280	0.0221	0.0339
7 1/4	7 3/8	7 1/2	0.0060	0.0000	0.0226	0.0286	0.0226	0.0346
7 3/8	7 1/2	7 5/8	0.0061	0.0000	0.0231	0.0292	0.0231	0.0353
7 1/2	7 5/8	7 3/4	0.0062	0.0000	0.0236	0.0298	0.0236	0.0360
7 5/8	7 3/4	7 7/8	0.0063	0.0000	0.0241	0.0304	0.0241	0.0367
7 3/4	7 7/8	8	0.0064	0.0000	0.0246	0.0310	0.0246	0.0374

*NOTE: + denotes clearances or amount of looseness.



SUMMARY OF DATA

	Hole	Shaft	
Tightest fit	1.2500	1.2484	0.0016 Allowance
Loosest fit	1.2514	1.2470	0.0044 Allowance + Tolerances

FORMULAS

When d = mean size,

Hole tolerance $= 0.0013\sqrt[3]{d}$

Shaft tolerance $= 0.0013\sqrt[3]{d}$

Allowance $= 0.0014\sqrt[3]{d^2}$

TABLE 4.—MEDIUM FIT (CLASS 3) —MEDIUM ALLOWANCE INTERCHANGEABLE

For running fits under 600 r.p.m. and with journal pressures less than 600 pounds per square inch; also for sliding fits, and the more accurate machine-tool and automotive parts.

(All Dimensions in Inches)

Size			Limits				Tightest Fit	Loosest Fit
			Hole or External Member		Shaft or Internal Member			
From	Up to and Inclusive	Mean	+		−	−	Allowance +*	Allowance + Tolerances +*
0	1/16	1/32	0.0004	0.0000	0.0002	0.0006	0.0002	0.0010
1/16	1/8	3/32	0.0005	0.0000	0.0004	0.0009	0.0004	0.0014
1/8	1/16	1/8	0.0006	0.0000	0.0005	0.0011	0.0005	0.0017
1/16	1/8	5/32	0.0006	0.0000	0.0006	0.0012	0.0006	0.0018
1/8	13/16	3/16	0.0007	0.0000	0.0007	0.0014	0.0007	0.0021
13/16	1 1/16	7/32	0.0007	0.0000	0.0007	0.0014	0.0007	0.0021
1 1/16	1 3/16	1/4	0.0008	0.0000	0.0008	0.0016	0.0008	0.0024
1 3/16	1 5/16	9/32	0.0008	0.0000	0.0008	0.0016	0.0008	0.0024
1 5/16	1 1/16	1	0.0008	0.0000	0.0009	0.0017	0.0009	0.0025
1 1/16	1 3/16	1 1/32	0.0008	0.0000	0.0010	0.0018	0.0010	0.0026
1 3/16	1 5/16	1 1/16	0.0009	0.0000	0.0010	0.0019	0.0010	0.0028
1 5/16	1 7/16	1 1/8	0.0009	0.0000	0.0012	0.0021	0.0012	0.0030
1 7/16	1 9/16	1 3/16	0.0010	0.0000	0.0013	0.0023	0.0013	0.0033
1 7/8	2 1/8	2	0.0010	0.0000	0.0014	0.0024	0.0014	0.0034
2 1/8	2 3/8	2 1/4	0.0010	0.0000	0.0015	0.0025	0.0015	0.0035
2 3/8	2 5/8	2 1/2	0.0011	0.0000	0.0017	0.0028	0.0017	0.0039
2 5/8	2 7/8	2 3/4	0.0012	0.0000	0.0019	0.0031	0.0019	0.0043
2 7/8	3 1/8	3	0.0012	0.0000	0.0021	0.0033	0.0021	0.0045
3 1/8	3 3/8	3 1/4	0.0013	0.0000	0.0023	0.0036	0.0023	0.0049
3 3/8	4 1/4	4						
4 1/4	4 3/4	4 1/2	0.0013	0.0000	0.0025	0.0038	0.0025	0.0051
4 3/4	5 1/2	5	0.0014	0.0000	0.0026	0.0040	0.0026	0.0054
5 1/2	6 1/2	6	0.0015	0.0000	0.0030	0.0045	0.0030	0.0060
6 1/2	7 1/2	7	0.0015	0.0000	0.0033	0.0048	0.0033	0.0063
7 1/2	8 1/2	8	0.0016	0.0000	0.0036	0.0052	0.0036	0.0068

*NOTE: + denotes clearance or amount of looseness.



SUMMARY OF DATA

	Hole	Shaft	
Tightest fit	3.0000	2.9981	0.0019 Allowance
Loosest fit	3.0012	2.9969	0.0043 Allowance + Tolerances

FORMULAS

When d = mean size,

Hole tolerance $= 0.0008\sqrt[3]{d}$

Shaft tolerance $= 0.0008\sqrt[3]{d}$

Allowance $= 0.0009\sqrt[3]{d^2}$

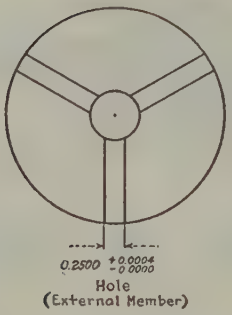
TABLE 5.—SNUG FIT (CLASS 4)—ZERO ALLOWANCE INTERCHANGEABLE

This is the closest fit which can be assembled by hand and necessitates work of considerable precision. It should be used where no perceptible shake is permissible and where moving parts are not intended to move freely under load.

(All Dimensions in Inches)

Size			Limits				Tightest Fit	Loosest Fit
From	Up to and Inclusive	Mean	Hole or External Member		Shaft or Internal Member		Allowance	Allowance + Tolerances
			+			−		+*
0	3/16	1/32	0.0003	0.0000	0.0000	0.0002	0.0000	0.0005
3/16	6/16	1/16	0.0004	0.0000	0.0000	0.0003	0.0000	0.0007
6/16	7/16	1/8	0.0004	0.0000	0.0000	0.0003	0.0000	0.0007
7/16	9/16	1/16	0.0005	0.0000	0.0000	0.0003	0.0000	0.0008
9/16	11/16	5/32	0.0005	0.0000	0.0000	0.0003	0.0000	0.0008
11/16	13/16	3/16	0.0005	0.0000	0.0000	0.0004	0.0000	0.0009
13/16	15/16	7/32	0.0006	0.0000	0.0000	0.0004	0.0000	0.0010
15/16	1 1/16	1/8	0.0006	0.0000	0.0000	0.0004	0.0000	0.0010
1 1/16	1 3/16	1	0.0006	0.0000	0.0000	0.0004	0.0000	0.0010
1 3/16	1 5/16	1 1/32	0.0006	0.0000	0.0000	0.0004	0.0000	0.0010
1 5/16	1 3/8	1 1/16	0.0006	0.0000	0.0000	0.0004	0.0000	0.0010
1 3/8	1 7/16	1 3/32	0.0007	0.0000	0.0000	0.0005	0.0000	0.0012
1 7/16	1 5/8	1 1/8	0.0007	0.0000	0.0000	0.0005	0.0000	0.0012
1 5/8	1 7/8	1 5/32	0.0007	0.0000	0.0000	0.0005	0.0000	0.0012
1 7/8	2 1/8	2	0.0008	0.0000	0.0000	0.0005	0.0000	0.0013
2 1/8	2 3/8	2 1/16	0.0008	0.0000	0.0000	0.0005	0.0000	0.0013
2 3/8	2 5/8	2 1/8	0.0008	0.0000	0.0000	0.0005	0.0000	0.0013
2 5/8	2 7/8	2 3/16	0.0009	0.0000	0.0000	0.0006	0.0000	0.0015
2 7/8	3 1/4	3	0.0009	0.0000	0.0000	0.0006	0.0000	0.0015
3 1/4	3 3/4	3 1/2	0.0009	0.0000	0.0000	0.0006	0.0000	0.0015
3 3/4	4 1/4	4	0.0010	0.0000	0.0000	0.0006	0.0000	0.0016
4 1/4	4 3/4	4 1/2	0.0010	0.0000	0.0000	0.0007	0.0000	0.0017
4 3/4	5 1/2	5	0.0010	0.0000	0.0000	0.0007	0.0000	0.0017
5 1/2	6 1/2	6	0.0011	0.0000	0.0000	0.0007	0.0000	0.0018
6 1/2	7 1/2	7	0.0011	0.0000	0.0000	0.0008	0.0000	0.0019
7 1/2	8 1/2	8	0.0012	0.0000	0.0000	0.0008	0.0000	0.0020

*NOTE: + denotes clearance or amount of looseness.



SUMMARY OF DIMENSIONS

	Hole	Shaft	
Tightest fit	0.2500	0.2500	0.0000 Allowance
Loosest fit	0.2504	0.2497	0.0007 Allowance + Tolerances

FORMULAS

When d = mean size,

Hole tolerance $= 0.0006\sqrt[3]{d}$

Shaft tolerance $= 0.0004\sqrt[3]{d}$

Allowance $= 0.0000$

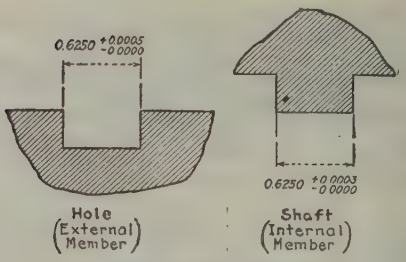
TABLE 6.—WRINGING FIT (CLASS 5)—ZERO TO NEGATIVE ALLOWANCE SELECTIVE ASSEMBLY

This is also known as a "tunking fit" and it is practically metal-to-metal. Assembly is usually selective and not interchangeable.

(All Dimensions in Inches)

Size			Limits				Tightest Fit	Loosest Fit	Selected Fit
			Hole or External Member		Shaft or Internal Member				
From	Up to and Inclusive	Mean	+	−	+	−	Allowance −*	Allowance + Tolerances +*	Average Interference of metal
0	3/16	1/8	0.0003	0.0000	0.0002	0.0000	0.0002	0.0003	0.0000
3/16	7/16	1/4	0.0004	0.0000	0.0003	0.0000	0.0003	0.0004	0.0000
7/16	11/16	3/8	0.0004	0.0000	0.0003	0.0000	0.0003	0.0004	0.0000
11/16	15/16	1/2	0.0005	0.0000	0.0003	0.0000	0.0003	0.0005	0.0000
15/16	1 3/16	5/8	0.0005	0.0000	0.0003	0.0000	0.0003	0.0005	0.0000
1 3/16	1 7/16	3/4	0.0005	0.0000	0.0004	0.0000	0.0004	0.0005	0.0000
1 7/16	1 11/16	7/8	0.0005	0.0000	0.0004	0.0000	0.0004	0.0006	0.0000
1 11/16	1 15/16	1	0.0006	0.0000	0.0004	0.0000	0.0004	0.0006	0.0000
1 15/16	2 3/16	1 1/8	0.0006	0.0000	0.0004	0.0000	0.0004	0.0006	0.0000
2 3/16	2 7/16	1 1/4	0.0006	0.0000	0.0004	0.0000	0.0004	0.0006	0.0000
2 7/16	2 11/16	1 1/2	0.0007	0.0000	0.0005	0.0000	0.0005	0.0007	0.0000
2 11/16	2 15/16	1 3/4	0.0007	0.0000	0.0005	0.0000	0.0005	0.0007	0.0000
2 15/16	3 3/16	2	0.0008	0.0000	0.0005	0.0000	0.0005	0.0008	0.0000
3 3/16	3 7/16	2 1/2	0.0008	0.0000	0.0005	0.0000	0.0005	0.0008	0.0000
3 7/16	3 11/16	2 1/2	0.0008	0.0000	0.0005	0.0000	0.0005	0.0008	0.0000
3 11/16	3 15/16	3	0.0009	0.0000	0.0006	0.0000	0.0006	0.0009	0.0000
3 15/16	4 3/16	3 1/2	0.0009	0.0000	0.0006	0.0000	0.0006	0.0009	0.0000
4 3/16	4 7/16	4	0.0010	0.0000	0.0006	0.0000	0.0006	0.0010	0.0000
4 7/16	4 11/16	4 1/2	0.0010	0.0000	0.0007	0.0000	0.0007	0.0010	0.0000
4 11/16	5 3/16	5	0.0010	0.0000	0.0007	0.0000	0.0007	0.0010	0.0000
5 3/16	6 3/16	6	0.0011	0.0000	0.0007	0.0000	0.0007	0.0011	0.0000
6 3/16	7 3/16	7	0.0011	0.0000	0.0008	0.0000	0.0008	0.0011	0.0000
7 3/16	8 3/16	8	0.0012	0.0000	0.0008	0.0000	0.0008	0.0012	0.0000

* − denotes interference of metal or negative allowance. + denotes clearance or amount of looseness.



SUMMARY OF DIMENSIONS

	Hole	Shaft	
Tightest fit	0.6250	0.6253	−0.0003
Loosest fit	0.6255	0.6250	+0.0005
Selected fit	0.6250	0.6250	0.0000

FORMULAS

When d = mean size,

Hole tolerance = $0.0006\sqrt[3]{d}$

Shaft tolerance = $0.0004\sqrt[3]{d}$

Average interference of metal = 0.0000

The average interference of metal is the desired condition and must be otained by selective assembly, that is, by mating large shafts in large holes and small shafts in small holes.

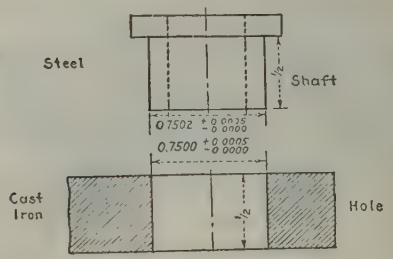
TABLE 7a.—TIGHT FIT (CLASS 6)—SLIGHT NEGATIVE ALLOWANCE SELECTIVE ASSEMBLY

Light pressure is required to assemble these fits and the parts are more or less permanently assembled, such as the fixed ends of studs for gears, pulleys, rocker arms, etc. These fits are used for drive fits in thin sections or extremely long fits in other sections, and also for shrink fits on very light sections. Used in automotive, ordnance and general machine manufacturing.

(All Dimensions in Inches)

Size			Limits				Tightest Fit	Loosest Fit	Selected Fit
			Hole or External Member		Shaft or Internal Member				
From	Up to and Inclusive	Mean	+		+	+	Allowance −*	Allowance + Tolerances *	Average Interference of metal −*
0	1/16	1/32	0.0003	0.0000	0.0003	0.0000	0.0003	+0.0003	0.0000
1/16	1/8	3/32	0.0004	0.0000	0.0005	0.0001	0.0005	+0.0003	0.0001
1/8	1/16	3/16	0.0004	0.0000	0.0005	0.0001	0.0005	+0.0003	0.0001
1/16	9/16	1/8	0.0005	0.0000	0.0006	0.0001	0.0006	+0.0004	0.0001
9/16	11/16	5/8	0.0005	0.0000	0.0007	0.0002	0.0007	+0.0003	0.0002
11/16	13/16	7/8	0.0005	0.0000	0.0007	0.0002	0.0007	+0.0003	0.0002
13/16	15/16	7/8	0.0006	0.0000	0.0008	0.0002	0.0008	+0.0004	0.0002
15/16	1 1/16	1	0.0006	0.0000	0.0009	0.0003	0.0009	+0.0003	0.0003
1 1/16	1 3/16	1 1/8	0.0006	0.0000	0.0009	0.0003	0.0009	+0.0003	0.0003
1 3/16	1 5/16	1 1/4	0.0006	0.0000	0.0009	0.0003	0.0009	+0.0003	0.0003
1 5/16	1 7/16	1 3/8	0.0007	0.0000	0.0011	0.0004	0.0011	+0.0003	0.0004
1 7/16	1 9/16	1 1/2	0.0007	0.0000	0.0011	0.0004	0.0011	+0.0003	0.0004
1 9/16	2 1/8	2	0.0008	0.0000	0.0013	0.0005	0.0013	+0.0003	0.0005
2 1/8	2 3/8	2 1/4	0.0008	0.0000	0.0014	0.0006	0.0014	+0.0002	0.0006
2 3/8	2 5/8	2 1/2	0.0008	0.0000	0.0014	0.0006	0.0014	+0.0002	0.0006
2 5/8	3 1/4	3	0.0009	0.0000	0.0017	0.0008	0.0017	+0.0001	0.0008
3 1/4	3 3/4	3 1/2	0.0009	0.0000	0.0018	0.0009	0.0018	−0.0000	0.0009
3 3/4	4 1/4	4	0.0010	0.0000	0.0020	0.0010	0.0020	−0.0000	0.0010
4 1/4	4 3/4	4 1/2	0.0010	0.0000	0.0021	0.0011	0.0021	−0.0001	0.0011
4 3/4	5 1/2	5	0.0010	0.0000	0.0023	0.0013	0.0023	−0.0003	0.0013
5 1/2	6 1/2	6	0.0011	0.0000	0.0026	0.0015	0.0026	−0.0004	0.0015
6 1/2	7 1/2	7	0.0011	0.0000	0.0029	0.0018	0.0029	−0.0007	0.0018
7 1/2	8 1/2	8	0.0012	0.0000	0.0032	0.0020	0.0032	−0.0008	0.0020

* − denotes interference of metal or negative allowance. + denotes clearance or amount of looseness.



SUMMARY OF DIMENSIONS

	Hole	Shaft	
Tightest fit	0.7500	0.7507	−0.0007
Loosest fit	0.7505	0.7502	+0.0003
†Selected fit	0.7500	0.7502	−0.0002
‡Selected fit	0.7505	0.7507	−0.0002

Hole stress = 2,608 pounds per square inch.
Force for pressing = ½ × 0.149 = 0.075 ton
† Small shaft in small hole.
‡ Large shaft in large hole.

FORMULAS

When d = mean size,

Hole tolerance = $0.0006\sqrt[3]{d}$

Shaft tolerance = $0.0006\sqrt[3]{d}$

Average interference of metal = $0.00025\ d$

The average interference of metal is the desired condition and must be obtained by selective assembly, that is, by mating large shafts in large holes and small shafts in small holes.

Mean Size	Interference of Metal per Inch of Mean Size, Inches			Greatest Hole Stress, Steel Shaft in Steel Hole, Pounds per Square Foot			Greatest Hole Stress, Steel Shaft in Cast-Iron Hole, Pounds per Square Foot			Force for Pressing Steel Shaft into Steel Hole, Tons			Force for Pressing Steel Shaft into Cast-Iron Hole, Tons		
	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit
$\frac{1}{2}$	0.00240	No values, due to smallest shaft member in largest hole member	0.00025	69,600	No values, due to smallest shaft member in largest hole member	7,250	25,037	No values, due to smallest shaft member in largest hole member	2,608	0.389	0.000	0.000	0.224	0.000	0.000
$\frac{5}{8}$	0.00200		0.00025	58,000		7,250	20,864		2,608	0.649	0.130	0.374			0.075
$\frac{3}{4}$	0.00133		0.00025	38,700		7,250	13,909		2,608	0.649	0.130	0.374			0.075
$\frac{7}{8}$	0.00120		0.00025	34,800		7,250	12,518		2,608	0.779	0.130	0.448			0.075
$\frac{15}{16}$	0.00112		0.00025	32,480		7,250	11,684		2,608	0.909	0.260	0.523			0.149
1	0.00093		0.00025	27,100		7,250	9,737		2,608	0.909	0.260	0.523			0.149
$1\frac{1}{16}$	0.00091		0.00025	26,500		7,250	9,538		2,608	1.038	0.260	0.598			0.149
$1\frac{1}{8}$	0.00090		0.00025	26,100		7,250	9,389		2,608	1.168	0.389	0.672			0.224
$1\frac{3}{16}$	0.00080		0.00025	23,200		7,250	8,346		2,608	1.168	0.389	0.672			0.224
$1\frac{1}{4}$	0.00072		0.00025	20,880		7,250	7,511		2,608	1.168	0.389	0.672			0.224
$1\frac{5}{16}$	0.00073		0.00025	21,300		7,250	7,650		2,608	1.428	0.519	0.822			0.299
$1\frac{3}{8}$	0.00063		0.00025	18,240		7,250	6,557		2,608	1.428	0.519	0.822			0.299
2	0.00065		0.00025	18,850		7,250	6,781		2,608	1.687	0.649	0.971			0.374
$2\frac{1}{8}$	0.00062		0.00025	18,040		7,250	6,491		2,608	1.817	0.779	1.046			0.448
$2\frac{1}{2}$	0.00056		0.00025	16,200		7,250	5,842		2,608	1.817	0.779	1.046			0.448
3	0.00057		0.00025	16,433		7,250	5,911		2,608	2.207	1.038	1.270			0.598
$3\frac{1}{2}$	0.00051		0.00025	14,910		7,250	5,365		2,608	2.336	1.168	1.345			0.672
4	0.00050		0.00025	14,500		7,250	5,216		2,608	2.596		1.298	1.494		0.747
$4\frac{1}{2}$	0.00047	0.00002	0.00025	13,530	644	7,250	4,868	232	2,608	2.726	0.130	1.428	1.569	0.075	0.822
5	0.00046	0.00006	0.00025	13,340	1,740	7,250	4,799	625	2,608	2.985	0.389	1.687	1.719	0.224	0.971
6	0.00043	0.00007	0.00025	12,570	1,933	7,250	4,521	695	2,608	3.375	0.519	1.947	1.942	0.299	1.121
7	0.00041	0.00010	0.00025	12,010	2,900	7,250	4,322	1,043	2,608	3.764	0.909	2.336	2.167	0.523	1.345
8	0.00040	0.00010	0.00025	11,600	2,900	7,250	4,173	1,043	2,608	4.154	1.038	2.596	2.391	0.598	1.494
				Stress = 29,000,000 A/d			Stress = 10,432,000 A/d			Force = 1.298 A			Force = 747.2 A		

A = allowance, d = mean size. Values for stress and force are true only when hub diameter equals twice the hole diameter. The force values are for fit 1 inch long. For other lengths multiply by the length of fit in inches.

The values of greatest hole stress are for a mean diameter sizes only. For other sizes in a step, the interference per inch of diameter and hence the greatest hole stress will vary from the values given in the table by less than 10 per cent. Where greater accuracy for the intermediate steps is required, the interference per inch of diameter should be obtained by use of the formula:

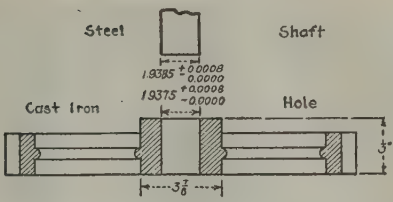
Table 8a.—Medium Force Fit (Class 7)—Negative Allowance Selective Assembly

Considerable pressure is required to assemble these fits and the parts are considered permanently assembled. These fits are used in fastening locomotive wheels, car wheels, armatures of dynamos and motors, and crank disks to their axles or shafts. They are also used for shrink fits on medium sections or long fits. These fits are the tightest which are recommended for cast-iron holes or external members as they stress cast iron to its elastic limit.

(All Dimensions in Inches.)

Size			Limit				Tightest Fit	Loosest Fit	Selected Fit
			Hole or External Member		Shaft or Internal Member				
From	Up to and Inclusive	Mean	+		+	+	Allowance −*	Allowance + Tolerances *	Average Interference of metal −*
0	3/16	1/8	0.0003	0.0000	0.0004	0.0001	0.0004	+0.0002	0.0001
3/16	1/4	7/32	0.0004	0.0000	0.0005	0.0001	0.0005	+0.0003	0.0001
1/4	7/16	11/32	0.0004	0.0000	0.0006	0.0002	0.0006	+0.0002	0.0002
7/16	9/16	1/2	0.0005	0.0000	0.0008	0.0003	0.0008	+0.0002	0.0003
9/16	11/16	5/8	0.0005	0.0000	0.0008	0.0003	0.0008	+0.0002	0.0003
11/16	13/16	3/4	0.0005	0.0000	0.0009	0.0004	0.0009	+0.0001	0.0004
13/16	15/16	7/8	0.0006	0.0000	0.0010	0.0004	0.0010	+0.0002	0.0004
15/16	1 1/16	1	0.0006	0.0000	0.0011	0.0005	0.0011	+0.0001	0.0005
1 1/16	1 3/16	1 1/8	0.0006	0.0000	0.0012	0.0006	0.0012	0.0000	0.0006
1 3/16	1 5/16	1 1/4	0.0006	0.0000	0.0012	0.0006	0.0012	0.0000	0.0006
1 5/16	1 7/16	1 3/8	0.0007	0.0000	0.0015	0.0008	0.0015	−0.0001	0.0008
1 7/16	1 9/16	1 1/2	0.0007	0.0000	0.0016	0.0009	0.0016	−0.0002	0.0009
1 1/2	2 1/8	2	0.0008	0.0000	0.0018	0.0010	0.0018	−0.0002	0.0010
2 1/8	2 3/8	2 1/4	0.0008	0.0000	0.0019	0.0011	0.0019	−0.0003	0.0011
2 3/8	2 5/8	2 1/2	0.0008	0.0000	0.0021	0.0013	0.0021	−0.0005	0.0013
2 5/8	3 1/8	3	0.0009	0.0000	0.0024	0.0015	0.0024	−0.0006	0.0015
3 1/8	3 3/8	3 1/4	0.0009	0.0000	0.0027	0.0018	0.0027	−0.0009	0.0018
3 3/8	4 1/2	4	0.0010	0.0000	0.0030	0.0020	0.0030	−0.0010	0.0020
4 1/2	4 3/4	4 1/2	0.0010	0.0000	0.0033	0.0023	0.0033	−0.0013	0.0023
4 1/2	5 1/2	5	0.0010	0.0000	0.0035	0.0025	0.0035	−0.0015	0.0025
5 1/2	6 1/2	6	0.0011	0.0000	0.0041	0.0030	0.0041	−0.0019	0.0030
6 1/2	7 1/2	7	0.0011	0.0000	0.0046	0.0035	0.0046	−0.0024	0.0035
7 1/2	8 1/2	8	0.0012	0.0000	0.0052	0.0040	0.0052	−0.0028	0.0040
8 1/2	9 1/2	9	0.0012	0.0000	0.0057	0.0045	0.0057	−0.0033	0.0045
10 1/2	11 1/2	10	0.0013	0.0000	0.0063	0.0050	0.0063	−0.0037	0.0050
11 1/2	13	12	0.0014	0.0000	0.0074	0.0060	0.0074	−0.0046	0.0060
13	15	14	0.0014	0.0000	0.0084	0.0070	0.0084	−0.0056	0.0070
15	17	16	0.0015	0.0000	0.0095	0.0080	0.0095	−0.0065	0.0080
17	19	18	0.0016	0.0000	0.0106	0.0090	0.0106	−0.0074	0.0090
19	22	20	0.0016	0.0000	0.0116	0.0100	0.0116	−0.0084	0.0100
22	26	24	0.0017	0.0000	0.0137	0.0120	0.0137	−0.0103	0.0120
26	30	28	0.0018	0.0000	0.0158	0.0140	0.0158	−0.0122	0.0140
30	34	32	0.0019	0.0000	0.0179	0.0160	0.0179	−0.0141	0.0160
34	38	36	0.0020	0.0000	0.0200	0.0180	0.0200	−0.0160	0.0180
38	44	40	0.0021	0.0000	0.0221	0.0200	0.0221	−0.0179	0.0200
44	52	48	0.0022	0.0000	0.0262	0.0240	0.0262	−0.0218	0.0240
52	60	56	0.0023	0.0000	0.0303	0.0280	0.0303	−0.0257	0.0280
60	68	64	0.0024	0.0000	0.0344	0.0320	0.0344	−0.0296	0.0320
68	76	72	0.0025	0.0000	0.0385	0.0360	0.0385	−0.0335	0.0360
76	88	80	0.0026	0.0000	0.0426	0.0400	0.0426	−0.0374	0.0400
88	104	96	0.0027	0.0000	0.0507	0.0480	0.0507	−0.0453	0.0480
104	120	112	0.0029	0.0000	0.0580	0.0560	0.0589	−0.0531	0.0560
120	136	128	0.0030	0.0000	0.0670	0.0640	0.0670	−0.0610	0.0640

* − denotes interference of metal or negative allowance. + denotes clearance or amount of looseness.



SUMMARY OF DIMENSIONS

	Hole	Shaft	
Tightest fit	1.9375	1.9393	−0.0018
Loosest fit	1.9383	1.9385	−0.0002
Selected fit	1.9375	1.9385	−0.0010
Selected fit	1.9383	1.9393	−0.0010

Hole stress = 5,216 pounds per square inch.
Force for pressing = 3 × 0.747 = 2.241 tons.

FORMULAS

When d = mean size,

Hole tolerance = 0.0006
Shaft tolerance = $0.0006\sqrt[3]{d}$
Average interference of metal = $0.0005d$.

The average interference of metal given is the desired condition and must be obtained by selective assembly, that is, by mating large shafts in large holes and small shafts in small holes.

For hole and shaft tolerances, the same formulas were used for sizes larger than 8 inches, although no data were available for these diameters.

TABLE 8*b*.—MEDIUM FORCE FIT (CLASS 7)—NEGATIVE ALLOWANCE SELECTIVE ASSEMBLY

Mean Size	Interference of Metal per inch of Mean Size, Inches			Greatest Hole Stress, Steel Shaft in						Force for Pressing Steel Shaft into					
				Steel Hole, Pounds per Square Inch			Cast Iron Hole, Pounds per Square Inch			Steel Hole, Tons			Cast Iron Hole, Tons		
	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit
[illegible]	0.00320	*	0.0005	92,800	*	14,500	33,382	*	5,216	0.519	*	0.130	0.299	*	0.075
	0.00200	*	0.0005	58,000	*	14,500	20,864	*	5,216	0.649	*	0.130	0.374	*	0.075
	0.00160	*	0.0005	46,400	*	14,500	16,691	*	5,216	0.779	*	0.200	0.448	*	0.149
	0.00160	*	0.0005	46,400	*	14,500	16,691	*	5,216	1.038	*	0.389	0.598	*	0.224
	0.00128	*	0.0005	37,120	*	14,500	13,353	*	5,216	1.038	*	0.389	0.598	*	0.224
	0.00120	*	0.0005	34,800	*	14,500	12,513	*	5,216	1.168	*	0.519	0.672	*	0.299
	0.00114	*	0.0005	33,140	*	14,500	11,922	*	5,216	1.298	*	0.519	0.747	*	0.299
1	0.00110	*	0.0005	31,900	*	14,500	11,475	*	5,216	1.428	*	0.649	0.822	*	0.374
1¼	0.00107	*	0.0005	30,930	*	14,500	11,127	*	5,216	1.558	*	0.779	0.897	*	0.448
1½	0.00096	*	0.0005	27,830	*	14,500	10,015	*	5,216	1.558	*	0.779	0.897	*	0.448
1¾	0.00100	0.00007	0.0005	29,000	1,934	14,500	10,432	695	5,216	1.947	0.130	1.038	1.121	0.075	0.598
1¾	0.00091	0.00011	0.0005	26,510	3,314	14,500	9,538	1,192	5,216	2.077	0.260	1.168	1.196	0.149	0.672
2	0.00090	0.00010	0.0005	26,100	2,900	14,500	9,389	1,043	5,216	2.336	0.260	1.298	1.345	0.149	0.747
2¼	0.00084	0.00013	0.0005	24,490	3,866	14,500	8,809	1,391	5,216	2.466	0.389	1.428	1.420	0.224	0.822
2½	0.00084	0.00020	0.0005	24,340	5,800	14,500	8,763	2,086	5,216	2.726	0.649	1.687	1.569	0.373	0.971
3	0.00080	0.00020	0.0005	23,200	5,800	14,500	8,346	2,086	5,216	3.115	0.779	1.947	1.793	0.448	1.121
3½	0.00077	0.00026	0.0005	22,370	7,457	14,500	8,048	2,682	5,216	3.505	1.168	2.336	2.017	0.672	1.345
4	0.00075	0.00025	0.0005	21,750	7,250	14,500	7,824	2,608	5,216	3.894	1.298	2.596	2.242	0.747	1.494
4½	0.00073	0.00029	0.0005	21,270	8,377	14,500	7,652	3,014	5,216	4.283	1.687	2.985	2.466	0.971	1.719
5	0.00070	0.00030	0.0005	20,300	8,700	14,500	7,302	3,130	5,216	4.543	1.947	3.245	2.615	1.121	1.868
6	0.00068	0.00032	0.0005	19,810	9,183	14,500	7,129	3,303	5,216	5.322	2.466	3.894	3.064	1.420	2.242
7	0.00066	0.00034	0.0005	19,060	9,942	14,500	6,855	3,577	5,216	5.971	3.115	4.543	3.437	1.793	2.615

8	0.00065	0.00035	0.0005	18,850	10,150	14,500	6,781	3,651	5,216	6.750	3.634	5.192	3.885	2.092	2.989
9	0.00063	0.00037	0.0005	18,370	10,630	14,500	6,607	3,875	5,216	7.399	4.283	5.841	4.259	2.466	3.362
10	0.00063	0.00037	0.0005	18,270	10,730	14,500	6,572	3,860	5,216	8.177	4.803	6.490	4.707	2.765	3.736
12	0.00062	0.00038	0.0005	17,890	11,120	14,500	6,433	3,999	5,216	9.605	5.971	7.788	5.529	3.437	4.483
14	0.00060	0.00040	0.0005	17,400	11,600	14,500	6,259	4,173	5,216	10.903	7.269	9.068	6.276	4.184	5.230
16	0.00059	0.00041	0.0005	17,220	11,780	14,500	6,194	4,238	5,216	12.331	8.437	10.384	7.098	4.857	5.978
18	0.00059	0.00041	0.0005	17,080	11,920	14,500	6,143	4,289	5,216	13.759	9.605	11.682	7.920	5.529	6.725
20	0.00058	0.00042	0.0005	16,820	12,180	14,500	6,051	4,381	5,216	15.057	10.903	12.980	8.668	6.276	7.472
24	0.00057	0.00043	0.0005	16,550	12,450	14,500	5,955	4,477	5,216	17.783	13.369	15.576	10.236	7.696	8.966
28	0.00056	0.00044	0.0005	16,360	12,640	14,500	5,887	4,173	5,216	20.508	14.538	18.172	11.806	8.369	10.461
32	0.00056	0.00044	0.0005	16,220	12,780	14,500	5,835	4,597	5,216	23.234	18.302	20.768	13.375	10.536	11.955
36	0.00056	0.00044	0.0005	16,110	12,890	14,500	5,796	4,636	5,216	25.960	20.768	23.364	14.944	11.955	13.450
40	0.00055	0.00045	0.0005	16,020	12,980	14,500	5,764	4,668	5,216	28.686	23.234	25.960	16.513	13.375	14.944
48	0.00055	0.00045	0.0005	15,830	13,170	14,500	5,694	4,738	5,216	34.008	28.296	31.152	19.577	16.289	17.933
56	0.00054	0.00046	0.0005	15,690	13,310	14,500	5,644	4,788	5,216	39.329	33.359	36.344	22.640	19.203	20.922
64	0.00054	0.00046	0.0005	15,570	13,410	14,500	5,607	4,825	5,216	44.651	38.421	41.536	25.704	22.117	23.910
72	0.00053	0.00047	0.0005	15,500	13,490	14,500	5,578	4,854	5,216	49.973	43.483	46.728	28.767	25.031	26.899
80	0.00053	0.00047	0.0005	15,440	13,560	14,500	5,555	4,877	5,216	55.295	48.545	51.920	31.831	27.945	29.888
96	0.00053	0.00047	0.0005	15,320	13,680	14,500	5,509	4,923	5,216	65.809	58.799	62.304	37.883	33.848	35.866
112	0.00053	0.00047	0.0005	15,250	13,750	14,500	5,486	4,946	5,216	76.452	68.924	72.688	44.010	39.676	41.843
128	0.00052	0.00048	0.0005	15,180	13,820	14,500	5,461	4,972	5,216	86.966	79.178	83.072	50.062	45.579	47.821

Stress = 29,000,000 A/d	Stress = 10,432,000 A/d	Force = 1,298 A	Force = 747.2 A

A = allowance, d = mean size.

Values for stress and force are true only when hub diameter equals twice the hole diameter.

The force values are for fit 1 inch long. For other lengths multiply by the length of fit in inches.

* No values, due to smallest shaft member being smaller than the largest hole member.

The values of greatest hole stress are for mean diameter sizes only. For other sizes in a step, the interference per inch of diameter and hence the greatest hole stress will vary from the values given in the table by less than 10 per cent. Where greater accuracy for the intermediate steps is required, the interference per inch of diameter should be obtained by use of the formula: Average interference of metal = 0.0005 d, in which d is the diameter of the hole for which the size of the shaft is being computed.

SUMMARY OF DIMENSIONS

	Hole	Shaft	
Tightest fit	56.0000	56.0583	−0.0583
Loosest fit	56.0023	56.0560	−0.0537
†Selected fit	56.0000	56.0560	−0.0560
‡Selected fit	56.0023	56.0583	−0.0560

Hole stress = 29,000 pounds per square inch.

† Small shaft in small hole.

‡ Large shaft in large hole.

FORMULAS

When d = mean size,

$$\text{Hole tolerance} = 0.0006\sqrt[3]{d}$$

$$\text{Shaft tolerance} = 0.0006\sqrt[3]{d}$$

$$\text{Average interference of metal} = 0.001d.$$

The average interference of metal given is the desired condition and must be obtained by selective assembly, that is, by mating large shafts in large holes and small shafts in small holes.

For hole and shaft tolerances, the same formulas were used for sizes larger than 8 inches, although there was no data available for these diameters.

TABLE 9a.—HEAVY FORCE AND SHRINK FIT (CLASS 8) -CONSIDERABLE NEGATIVE ALLOWANCE SELECTIVE ASSEMBLY

These fits are used for steel holes where the metal can be stressed to its elastic limit. These fits cause excessive stress for cast-iron holes. Shrink fits are used where heavy force fits are impractical, as on locomotive wheel tires, heavy crank disks of large engines, etc.

(All Dimensions in Inches)

Size			Limits				Tightest Fit	Loosest Fit	Selected Fit
			Hole or External Member		Shaft or Internal Member		Allowance	Allowance + tolerances	Average interference of metal
From	Up to and Inclusive	Mean	+		+	+	−*	*	−*
0	3/16	1/8	0.0003	0.0000	0.0004	0.0001	0.0004	+0.0002	0.0001
3/16	5/16	1/4	0.0004	0.0000	0.0007	0.0003	0.0007	+0.0001	0.0003
5/16	7/16	3/8	0.0004	0.0000	0.0008	0.0004	0.0008	−0.0000	0.0004
7/16	9/16	1/2	0.0005	0.0000	0.0010	0.0005	0.0010	0.0000	0.0005
9/16	11/16	5/8	0.0005	0.0000	0.0011	0.0006	0.0011	−0.0001	0.0006
11/16	13/16	3/4	0.0005	0.0000	0.0013	0.0008	0.0013	−0.0003	0.0008
13/16	15/16	7/8	0.0006	0.0000	0.0015	0.0009	0.0015	−0.0003	0.0009
15/16	1 1/16	1	0.0006	0.0000	0.0016	0.0010	0.0016	−0.0004	0.0010
1 1/16	1 3/16	1 1/8	0.0006	0.0000	0.0017	0.0011	0.0017	−0.0005	0.0011
1 3/16	1 5/16	1 1/4	0.0006	0.0000	0.0019	0.0013	0.0019	−0.0007	0.0013
1 5/16	1 7/16	1 3/8	0.0007	0.0000	0.0022	0.0015	0.0022	−0.0008	0.0015
1 7/16	1 9/16	1 1/2	0.0007	0.0000	0.0025	0.0018	0.0025	−0.0011	0.0018
1 9/16	2 1/16	2	0.0008	0.0000	0.0028	0.0020	0.0028	−0.0012	0.0020
2 1/16	2 3/16	2 1/8	0.0008	0.0000	0.0031	0.0023	0.0031	−0.0015	0.0023
2 3/16	2 5/16	2 1/4	0.0008	0.0000	0.0033	0.0025	0.0033	−0.0017	0.0025
2 5/16	2 7/16	2 3/8	0.0009	0.0000	0.0036	0.0030	0.0036	−0.0021	0.0030
2 7/16	2 9/16	2 1/2	0.0009	0.0000	0.0039	0.0030	0.0039	−0.0021	0.0030
2 9/16	3 1/16	3	0.0009	0.0000	0.0044	0.0035	0.0044	−0.0026	0.0035
3 1/16	3 3/16	3 1/8	0.0009	0.0000	0.0044	0.0035	0.0044	−0.0026	0.0035
3 3/16	3 5/16	3 1/4	0.0010	0.0000	0.0050	0.0040	0.0050	−0.0030	0.0040
3 5/16	3 7/16	3 3/8	0.0010	0.0000	0.0050	0.0040	0.0050	−0.0030	0.0040
3 7/16	3 9/16	3 1/2	0.0010	0.0000	0.0055	0.0045	0.0055	−0.0035	0.0045
3 9/16	4 1/16	4	0.0010	0.0000	0.0060	0.0050	0.0060	−0.0040	0.0050
4 1/16	4 3/16	4 1/8	0.0010	0.0000	0.0060	0.0050	0.0060	−0.0040	0.0050
4 3/16	4 5/16	4 1/4	0.0010	0.0000	0.0060	0.0050	0.0060	−0.0040	0.0050
4 5/16	4 7/16	4 3/8	0.0011	0.0000	0.0071	0.0060	0.0071	−0.0049	0.0060
4 7/16	4 9/16	4 1/2	0.0011	0.0000	0.0071	0.0060	0.0071	−0.0049	0.0060
4 9/16	5 1/16	5	0.0010	0.0000	0.0060	0.0050	0.0060	−0.0040	0.0050
5 1/16	5 3/16	5 1/8	0.0011	0.0000	0.0071	0.0060	0.0071	−0.0049	0.0060
5 3/16	5 5/16	5 1/4	0.0011	0.0000	0.0071	0.0060	0.0071	−0.0049	0.0060
5 5/16	5 7/16	5 3/8	0.0011	0.0000	0.0071	0.0060	0.0071	−0.0049	0.0060
5 7/16	5 9/16	5 1/2	0.0011	0.0000	0.0071	0.0060	0.0071	−0.0049	0.0060
5 9/16	6 1/16	6	0.0011	0.0000	0.0071	0.0060	0.0071	−0.0049	0.0060
6 1/16	6 3/16	6 1/8	0.0011	0.0000	0.0071	0.0060	0.0071	−0.0049	0.0060
6 3/16	6 5/16	6 1/4	0.0011	0.0000	0.0071	0.0060	0.0071	−0.0049	0.0060
6 5/16	6 7/16	6 3/8	0.0011	0.0000	0.0071	0.0060	0.0071	−0.0049	0.0060
6 7/16	6 9/16	6 1/2	0.0011	0.0000	0.0071	0.0060	0.0071	−0.0049	0.0060
6 9/16	7 1/16	7	0.0011	0.0000	0.0081	0.0070	0.0081	−0.0059	0.0070
7 1/16	7 3/16	7 1/8	0.0011	0.0000	0.0081	0.0070	0.0081	−0.0059	0.0070
7 3/16	7 5/16	7 1/4	0.0011	0.0000	0.0081	0.0070	0.0081	−0.0059	0.0070
7 5/16	7 7/16	7 3/8	0.0011	0.0000	0.0081	0.0070	0.0081	−0.0059	0.0070
7 7/16	7 9/16	7 1/2	0.0011	0.0000	0.0081	0.0070	0.0081	−0.0059	0.0070
7 9/16	8 1/16	8	0.0012	0.0000	0.0092	0.0080	0.0092	−0.0068	0.0080
8 1/16	8 3/16	8 1/8	0.0012	0.0000	0.0092	0.0080	0.0092	−0.0068	0.0080
8 3/16	8 5/16	8 1/4	0.0012	0.0000	0.0092	0.0080	0.0092	−0.0068	0.0080
8 5/16	8 7/16	8 3/8	0.0012	0.0000	0.0092	0.0080	0.0092	−0.0068	0.0080
8 7/16	8 9/16	8 1/2	0.0012	0.0000	0.0092	0.0080	0.0092	−0.0068	0.0080
8 9/16	9 1/16	9	0.0012	0.0000	0.0102	0.0090	0.0102	−0.0078	0.0090
9 1/16	9 3/16	9 1/8	0.0012	0.0000	0.0102	0.0090	0.0102	−0.0078	0.0090
9 3/16	9 5/16	9 1/4	0.0012	0.0000	0.0102	0.0090	0.0102	−0.0078	0.0090
9 5/16	9 7/16	9 3/8	0.0012	0.0000	0.0102	0.0090	0.0102	−0.0078	0.0090
9 7/16	9 9/16	9 1/2	0.0012	0.0000	0.0102	0.0090	0.0102	−0.0078	0.0090
9 9/16	10 1/16	10	0.0013	0.0000	0.0113	0.0100	0.0113	−0.0087	0.0100
10 1/16	11 1/2	10	0.0013	0.0000	0.0113	0.0100	0.0113	−0.0087	0.0100
11 1/2	13	12	0.0014	0.0000	0.0134	0.0120	0.0134	−0.0106	0.0120
13	15	14	0.0014	0.0000	0.0154	0.0140	0.0154	−0.0126	0.0140
15	17	16	0.0015	0.0000	0.0175	0.0160	0.0175	−0.0145	0.0160
17	19	18	0.0016	0.0000	0.0196	0.0180	0.0196	−0.0164	0.0180
19	22	20	0.0016	0.0000	0.0216	0.0200	0.0216	−0.0184	0.0200
22	26	24	0.0017	0.0000	0.0257	0.0240	0.0257	−0.0223	0.0240
26	30	28	0.0018	0.0000	0.0298	0.0280	0.0298	−0.0262	0.0280
30	34	32	0.0019	0.0000	0.0339	0.0320	0.0339	−0.0301	0.0320
34	38	36	0.0020	0.0000	0.0380	0.0360	0.0380	−0.0340	0.0360
38	44	40	0.0021	0.0000	0.0421	0.0400	0.0421	−0.0379	0.0400
44	52	48	0.0022	0.0000	0.0502	0.0480	0.0502	−0.0458	0.0480
52	60	56	0.0023	0.0000	0.0583	0.0560	0.0583	−0.0537	0.0560
60	68	64	0.0024	0.0000	0.0664	0.0640	0.0664	−0.0616	0.0640
68	76	72	0.0025	0.0000	0.0745	0.0720	0.0745	−0.0695	0.0720
76	88	80	0.0026	0.0000	0.0826	0.0800	0.0826	−0.0774	0.0800
88	104	96	0.0027	0.0000	0.0987	0.0960	0.0987	−0.0933	0.0960
104	120	112	0.0029	0.0000	0.1149	0.1120	0.1149	−0.1091	0.1120
120	136	128	0.0030	0.0000	0.1310	0.1280	0.1310	−0.1250	0.1280

* − denotes interference of metal or negative allowance. + denotes clearance or amount of looseness.

TABLE 9*b*.—HEAVY FORCE AND SHRINK FIT (CLASS 8)—CONSIDERABLE NEGATIVE ALLOWANCE SELECTIVE ASSEMBLY

Mean Size	Interference of Metal per Inch of Mean Size, Inches			Greatest Hole Stress, Steel Shaft in Steel Hole, Pounds per Square Inch			Force for Pressing, Steel Shaft into Steel Hole, Tons		
	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit	Tightest Fit	Loosest Fit	Selected Fit
1/4	0.00320	*	0.001	92,800	*	29,000	0.519	*	0.130
5/16	0.00280	*	0.001	81,200	*	29,000	0.909	*	0.389
3/8	0.00213	*	0.001	61,870	*	29,000	1.038	*	0.519
7/16	0.00200	*	0.001	58,000	*	29,000	1.298	*	0.649
1/2	0.00176	0.00016	0.001	51,040	4,640	29,000	1.428	0.130	0.779
9/16	0.00173	0.00040	0.001	42,270	11,600	29,000	1.687	0.389	1.038
5/8	0.00171	0.00034	0 001	49,710	9.943	29,000	1.947	0.389	1.168
1	0.00160	0.00040	0.001	46,400	11,600	29,000	2.077	0.519	1.298
1 1/8	0.00151	0.00044	0.001	43,840	12,890	29,000	2.207	0.649	1.428
1 1/4	0.00152	0.00056	0.001	44,080	16,230	29,000	2.466	0.909	1.687
1 3/8	0.00147	0.00053	0.001	42,530	15,470	29,000	2.856	1.038	1.947
1 1/2	0.00143	0.00062	0.001	41,430	18,230	29,000	3.245	1.428	2.336
2	0.00140	0.00060	0.001	40,600	17,400	29,000	3.634	1.558	2.596
2 1/4	0.00138	0.00066	0.001	39,960	17,910	29,000	4.024	1.947	2.985
2 1/2	0.00132	0.00068	0.001	38,280	19,720	29,000	4.283	2.207	3.245
3	0.00130	0.00070	0.001	37,700	20,300	29,000	5 062	2.726	3.894
3 1/2	0.00126	0.00074	0.001	36,460	21,540	29,000	5.711	3.375	4.543
4	0.00125	0.00075	0.001	36,250	21,750	29,000	6.490	3.894	5.192
4 1/2	0.00122	0.00078	0.001	35.440	22,560	29,000	7.139	4.543	5.841
5	0.00120	0.00080	0.001	34.800	23.200	29,000	7.788	5.192	6 490
6	0.00118	0.00082	0.001	34.317	23.680	29,000	9.216	6.360	7.788
7	0.00116	0.00084	0.001	33.570	24.449	29,000	10.514	7.658	9.086
8	0.00115	0 00085	0.001	33.350	24.650	29,000	11.942	8.826	10 384

9	0.00113	0.00087	0.001	32,870	25,130	29,000	13.240	10.124	11.682
10	0.00113	0.00087	0.001	32,770	25,233	29,000	14.667	11.293	12.980
12	0.00112	0.00088	0.001	32,390	25,610	29,000	17.393	13.759	15.576
14	0.00110	0.00090	0.001	31,900	26,100	29,000	19.989	16.355	18.172
16	0.00109	0.00091	0.001	31,720	26,290	29,000	22.715	18.821	20.768
18	0.00108	0.00091	0.001	31,580	26,420	29,000	25.441	21.287	23.364
20	0.00108	0.00092	0.001	31,370	26,680	29,000	28.037	23.883	25.960
24	0.00107	0.00093	0.001	31,050	26,940	29,000	33.359	28.945	31.152
28	0.00106	0.00094	0.001	30,860	27,130	29,000	38.680	34.008	36.344
32	0.00106	0.00094	0.001	30,710	27,280	29,000	44.002	39.070	41.536
36	0.00106	0.00094	0.001	30,600	27,390	29,000	49.324	44.132	46.728
40	0.00105	0.00095	0.001	30,510	27,480	29,000	54.646	49.194	51.920
48	0.00105	0.00095	0.001	30,330	27,680	29,000	65.160	59.448	62.304
56	0.00104	0.00096	0.001	30,190	27,810	29,000	75.673	69.703	72.688
64	0.00104	0.00096	0.001	30,080	27,900	29,000	86.187	79.957	83.072
72	0.00103	0.00097	0.001	30,000	27,990	29,000	96.701	90.211	93.456
80	0.00103	0.00097	0.001	29,940	28,060	29,000	107.113	100.465	103.840
96	0.00103	0.00097	0.001	29,810	28,180	29,000	128.115	121.103	124.608
112	0.00103	0.00097	0.001	29,750	28,250	29,000	149.140	141.612	145.376
128	0.00102	0.00098	0.001	29,690	28,320	29,000	170.038	162.250	166.144
				Stress = 29,000,000 A/d			Force = 1298 A		

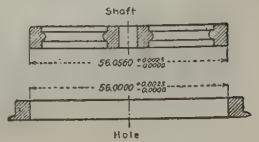
A = allowance, d = mean size.

Values for stress and force are true only when hub diameter equals twice the hole diameter.

The force values are for a fit 1 inch long. For other lengths multiply by the length of fit in inches.

* No values, due to smallest shaft member being smaller than the largest hole member.

The values of greatest hole stress are for mean diameter sizes only. For other sizes in a step, the interference per inch of diameter and hence the greatest hole stress will vary from the values given in the table by less than 10 per cent. Where greater accuracy for the intermediate steps is required, the interference per inch of diameter should be obtained by use of the formula: Average interference of metal = $0.001d$, in which d is the diameter of the hole for which the size of the shaft is being computed.



Formulas for Recommended Allowances and Tolerances

Class of Fit	Method of Assembly	Allowance	Selected Average Interference of Metal	Hole Tolerance	Shaft Tolerance
1. Loose	Strictly interchangeable	$0.0025\sqrt[3]{d^2}$	....	$0.0025\sqrt[3]{d}$	$0.0025\sqrt[3]{d}$
2. Free	Strictly interchangeable	$0.0014\sqrt[3]{d^2}$	....	$0.0013\sqrt[3]{d}$	$0.0013\sqrt[3]{d}$
3. Medium	Strictly interchangeable	$0.0009\sqrt[3]{d^2}$	....	$0.0008\sqrt[3]{d}$	$0.0008\sqrt[3]{d}$
4. Snug	Strictly interchangeable	0.0000	....	$0.0006\sqrt[3]{d}$	$0.0004\sqrt[3]{d}$
5. Wringing	Selective assembly	....	0.0000	$0.0006\sqrt[3]{d}$	$0.0004\sqrt[3]{d}$
6. Tight	Selective assembly	....	$0.00025d$	$0.0006\sqrt[3]{d}$	$0.0006\sqrt[3]{d}$
7. Medium force	Selective assembly	....	$0.0005d$	$0.0006\sqrt[3]{d}$	$0.0006\sqrt[3]{d}$
8. Heavy force or shrink	Selective assembly	....	$0.001d$	$0.0006\sqrt[3]{d}$	$0.0006\sqrt[3]{d}$
9. Reciprocating	Interchangeable	0.0000		$0.0008\sqrt[3]{d}$	$0.0008\sqrt[3]{d}$

d = diameter of fit in inches.
The formulas for allowance values give the ideal condition of fit for Classes 1 to 4.
The formulas for selected average interference of metal give the ideal condition of fit for Classes 5 to 8.

Explanatory Notes

In the table reproduced below many of the terms in common use in the shops of the country are given with the equivalent term which this Committee's report recommends:

Greatest tightness Least looseness Tighest fit Neutral zone Maximum metal	Are all common terms which have the same meaning as—	ALLOWANCE
Least tightness Greatest looseness Loosest fit Minimum metal	Are all common terms which have the same meaning as —	ALLOWANCE PLUS TOLERANCES
Difference between largest and smallest permissible size of either members. Variation in the size allowed	Now termed—	TOLERANCE

The basis for the foregoing recommended allowances and tolerances is a classification of fits quite commonly known to the manufacturing public. Interference between mating parts takes place at the exact basic value of the dimension; hence an accepted pair of mating standard gages become the "go" gages for mating parts which will prevent interference at the basic value of the dimension.

On account of the lack of a uniform and acceptable method of measuring the fitting surfaces of the external members of a pair of mating parts, it is recommended that plugs, blocks, disks and rods govern the checking of external members for the reason that usually the same measuring device will check for accuracy both the internal member and the gage for the external member, thus avoiding an interference when both members appear to have the same dimension.

To illustrate: If a 2-inch hole be measured with an inside micrometer and a shaft be measured with an outside micrometer, and both measure exactly 2 inches, there is no assurance they will go together; but, unless there were a definite understanding in a contract, the pieces might be ruled acceptable by law. If, however, the 2-inch hole would receive a plug gage which measured exactly 2 inches by a measuring machine, it would also receive an accurately finished shaft of the same size when measured by the same machine.

It is well known that a correct pair of plug and ring gages 2 inches in diameter will each check parts that will go together. It is also well known that the character of fit depends on the rotundity, parallelism, size and, in some cases, contour of the mating parts,

and that for cylindrical fits in mating parts, plug and ring gages are the only sure means of determining whether or not parts will go together. If either member of a pair of mating parts is three- or five-cornered, a snap gage or micrometer will not insure their going together.

In the foregoing allowances and tolerances, the best practice available was considered, and where differences occurred a compromise was attempted. The tolerances on holes apply only to reamed holes, or holes having a finish equivalent to reaming. From the standpoint of satisfactory performance, the tightest and loosest fits permissible are the all-important considerations. From a manufacturing standpoint, tolerances are the important factors. Hence both the tightest and loosest fits permissible must combine the tolerance and allowance, and therefore both allowance and tolerance must be considered for all-around satisfactory conditions.

It is not deemed to be feasible to include in this report allowances and tolerances which will apply to all work. In the industries many so-called standard fits are made which are not interchangeable, and an attempt to make them so would be prohibitive in cost. These fits, however, must be made on a production basis, and it is believed that the tables here given will be found to contain allowances and tolerances which are suitable for most work, even if some selection or individual fitting of parts is desired.

In choosing the class of fit for manufacture, the engineer should keep in mind that cost usually increases proportionately to the accuracy required, and no finer class of fit should be chosen than the functional requirements actually demand. It is axiomatic that the closer the fit the smaller the manufacturing tolerance, and usually the greater the cost. The length of engagement of the fit also plays an important part in the selection of the class of fit for a piece of work. It is obvious that a long engagement will tolerate more looseness than a short one, and due regard should be paid to this feature.

MAKING PRESS FITS

A formula for finding the pressure, in tons, required for forcing together mating parts having various allowances is:

$$P = \frac{A \times a \times F}{2}.$$

A formula for the allowances required to force mating parts together at certain pressures, in tons, is:

$$a = \frac{2P}{AF}.$$

In both formulas, A is the area of contact of the parts, in square inches; a is the total allowances of size, in inches; P is the pressure, in tons, required to force the parts together; F is the pressure factor given in the accompanying table.

Diameter of Work, Inches	Pressure Factor	Diameter of Work, Inches	Pressure Factor
1	500	5	91
1½	325	6	75
2	240	7	64
2½	189	8	55
3	156	9	48.7
3½	132	10	43.5
4	115	11	39.3
4½	101	12	35.9

EXAMPLE.—To find pressure required to force a 3-inch bar into a hole 3 inches long with an allowance of 0.003 inch or 0.001 per inch of diam. Circumference is 9.42 inches × length of 3 inches = 28.26-square inches area of contact. The factor for a 3-inch hole is 156, so the formula is $P = \frac{28.26 \times 0.003 \times 156}{2} = 6.61$ tons. To find allowance necessary to require a given pressure use second formula. Assume 10 tons is desired for the same parts as before.

$$a = \frac{2 \times 10}{28.26 \times 156} = 0.0045 \text{ inch allowance.}$$

A. S. M. E. SPECIFICATIONS FOR PLAIN LIMIT GAGES

The following specifications are for the purpose of establishing definite limits for plain limit gages rather than for the purpose of specifying the gages required for the various inspection operations.

Gages are classified according to accuracy into Classes X, Y and Z, the Class X being the closest to the extreme limits. The toler-

ance limits on Classes Y and Z "go" gages are placed inside of the extreme product limits to provide allowance for wear of the gages. The tolerances on all "not go" gages, however, are applied from the extreme product limit as the starting point, as no allowance for wear is necessary. The selection of gages from among these classes for use in the inspection of product depends entirely upon the specifications for the product. For example, Table 4, page 514, in the production of parts to Class 3, Medium Fit Specifications, Class X gages may be required for all purposes. For parts made to Class 1, Loose Fit Specifications, Class Z gages may be satisfactory for all purposes.

Gages should be tested periodically for wear and to insure that they are properly distributed. When successive inspections in the same plant are involved, it is good practice to inspect all gages of the same nominal size against each other periodically, and to distribute these gages so that the earlier inspections are made of those which are the greatest amount inside of the component limits, while the later inspections will be made of those which are closest in size to the component limits. "Go" gages may be permitted to wear to the extreme product limits. It is purely a question of economy as to when the "not go" gage should be discarded. Continued use reduces the available working tolerance on the product, and the resulting loss must be balanced against the cost of a new gage.

Plain plug gages of 1½-inches and less diameter should be made with plug inserted in the handle and securely fastened. Plain plug gages of more than 1½-inches diameter should have the gaging blank so made as to be reversible. The "not go" plain plug gage should be distinguished from the "go" gage by having it noticeably shorter.

Ring gages—both "go" and "not go" should, if made circular, have their outside diameters knurled. The "not go" ring should be distinguished from the "Go" ring by being noticeably thinner.

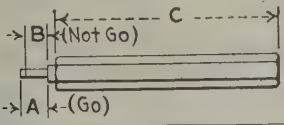
Snap gages may be either adjustable or non-adjustable. It is recommended that all snap gages up to and including ⅛ inch be of the built-up type. Sufficient clearance in the depth of the gage should be provided to permit the gaging of cylindrical work.

Snap gages for measuring lengths and diameters may have one gaging dimension only, or may have a maximum and minimum gaging dimension, both on one end, or on opposite ends of the gage. When the maximum and minimum gaging dimensions are placed on opposite ends of the gage, the maximum or "go" end of the snap gage should be distinguished from the minimum or "not go" and by having the corners of the gage on the "go" end noticeably chamfered.

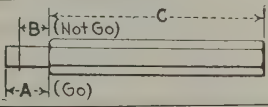
Dimensions recommended for plain plug, ring and snap gages are as follows:

Single-End Plug Gages

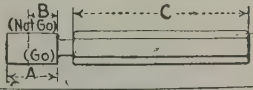
Turn groove on handle of "not go" gages only for identification.
(Dimensions in Inches)



Nominal Size		A	B	C	Size of Hex Handle
Over	To				
$\frac{1}{16}$	$\frac{1}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	2	$\frac{1}{4}$
	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	2	$\frac{1}{4}$

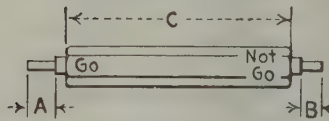


Nominal Size		A	B	C	Size of Hex Handle
Over	To				
$\frac{1}{8}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{1}{4}$	$2\frac{1}{2}$	$\frac{3}{8}$
$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{6}{16}$	$2\frac{1}{2}$	$\frac{3}{8}$

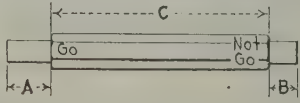


Nominal Size		A	B	C	Size of Hex Handle
Over	To				
$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{3}{8}$	$2\frac{1}{2}$	$\frac{3}{8}$
$\frac{5}{16}$	$\frac{3}{8}$	$\frac{9}{16}$	$\frac{1}{2}$	3	$\frac{1}{2}$
$\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{8}$	$\frac{1}{2}$	3	$\frac{1}{2}$
$\frac{1}{2}$	$\frac{5}{8}$	1	$\frac{1}{2}$	$3\frac{1}{2}$	$\frac{5}{8}$
$\frac{5}{8}$	$\frac{3}{4}$	$1\frac{1}{8}$	$\frac{1}{2}$	$3\frac{1}{2}$	$\frac{5}{8}$
$\frac{3}{4}$	$\frac{15}{16}$	$1\frac{1}{4}$	$\frac{5}{8}$	$3\frac{1}{2}$	$\frac{5}{8}$
$\frac{15}{16}$	$1\frac{1}{8}$	$1\frac{3}{8}$	$\frac{3}{4}$	4	$\frac{7}{8}$
$1\frac{1}{2}$	2	$1\frac{1}{2}$	$\frac{3}{4}$	4	$\frac{7}{8}$
2	$2\frac{1}{2}$	$1\frac{5}{8}$	$\frac{3}{4}$	$4\frac{1}{2}$	$1\frac{1}{8}$
$2\frac{1}{2}$	3	$1\frac{3}{4}$	$\frac{3}{4}$	$4\frac{1}{2}$	$1\frac{1}{8}$
3	4	$1\frac{7}{8}$	$\frac{3}{4}$	5	$1\frac{3}{8}$
4	5	2	$\frac{3}{4}$	5	$1\frac{3}{8}$
5	6	2	$\frac{3}{4}$	5	$1\frac{3}{8}$

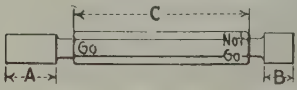
Double-End Plug Gages
(Dimensions in Inches)



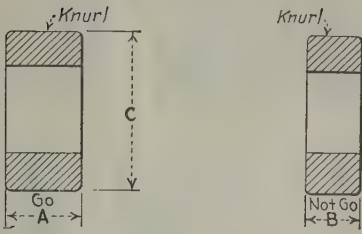
Nominal Size		A	B	C	Size of Hex Handle
Over	To				
	1/16	1/4	3/16	2	1/4
1/16	1/8	1/4	3/16	2	1/4



Nominal Size		A	B	C	Size of Hex Handle
Over	To				
1/8	3/16	3/8	1/4	2 1/2	3/8
3/16	1/4	1/2	5/16	2 1/2	3/8

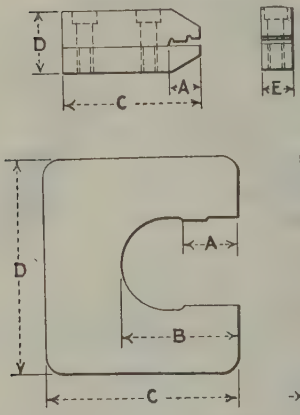


Nominal Size		A	B	C	Size of Hex Handle
Over	To				
1/4	5/16	5/8	3/8	2 1/2	3/8
5/16	3/8	3/4	1/2	3	1/2
3/8	1/2	7/8	1/2	3	1/2
1/2	5/8	1	1/2	3 1/2	5/8
5/8	3/4	1 1/8	1/2	3 1/2	5/8
3/4	15/16	1 1/4	5/8	3 1/2	5/8
15/16	1 1/2	1 3/8	3/4	4	7/8



Ring Gages
(Dimensions in Inches)

Nominal Size		A	B	C	Nominal Size		A	B	C
Over	To				Over	To			
	1/16	3/16	1/8	3/4	1 1/4	1 5/16	1	3/4	2 1/4
1/16	1/8	1/4	3/16	7/8	1 5/16	1 3/8	1 1/16	3/4	2 5/16
1/8	3/16	5/16	1/4	1 1/16	1 3/8	1 7/16	1 1/16	3/4	2 3/4
3/16	1/4	3/8	1/4	1	1 7/16	1 1/2	1 1/8	3/4	2 7/8
1/4	5/16	7/16	1/4	1 1/16	1 1/2	1 9/16	1 1/8	3/4	2 5/8
5/16	3/8	1/2	5/16	1 1/8	1 9/16	1 5/8	1 3/16	3/4	2 1/2
3/8	7/16	1/2	5/16	1 3/16	1 5/8	1 11/16	1 3/16	3/4	2 15/16
7/16	1/2	9/16	5/16	1 1/4	1 11/16	1 3/4	1 1/4	3/4	2 1/16
1/2	9/16	9/16	5/16	1 3/8	1 3/4	1 13/16	1 1/4	3/4	3
9/16	5/8	5/8	3/8	1 7/16	1 13/16	1 7/8	1 5/16	3/4	3 1/16
5/8	11/16	5/8	3/8	1 1/2	1 7/8	1 15/16	1 5/16	3/4	3 1/16
11/16	3/4	3/4	7/16	1 5/8	1 15/16	2	1 3/8	3/4	3 1/8
3/4	13/16	3/4	7/16	1 5/8	2	2 1/16	1 3/8	7/8	3 7/16
13/16	7/8	13/16	1/2	1 11/16	2 1/16	2 1/8	1 7/16	7/8	3 1/2
7/8	15/16	13/16	1/2	1 11/16	2 1/8	2 3/16	1 7/16	7/8	3 9/16
15/16	1	7/8	1/2	1 3/4	2 3/16	2 1/4	1 1/2	7/8	3 5/8
1	1 1/16	7/8	5/8	1 7/8	2 1/4	2 5/16	1 1/2	7/8	3 11/16
1 1/16	1 1/8	15/16	5/8	1 15/16	2 5/16	2 3/8	1 9/16	1	3 3/4
1 1/8	1 3/16	15/16	5/8	2	2 3/8	2 7/16	1 9/16	1	3 13/16
1 3/16	1 1/4	1	3/4	2 1/8	2 7/16	2 1/2	1 5/8	1	3 7/8

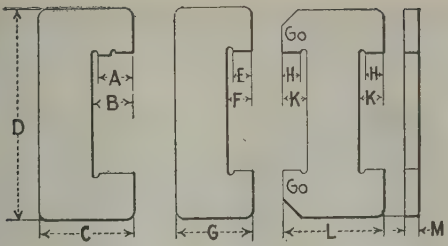


SNAP GAGES FOR DIAMETERS

Where standard adjustable gages cannot conveniently be used
(Dimensions in Inches)

Nominal Size	*A*	*C*	*D*	*E*
Up to $\frac{1}{8}$	$\frac{3}{8}$	$1\frac{5}{8}$	$\frac{11}{16}$	$\frac{7}{16}$

Nominal Size		*A*	*B*	*C*	*D*	*E*
Over	To					
$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{5}{8}$	$1\frac{5}{8}$	1	$\frac{1}{8}$
$\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{1}{4}$	$\frac{1}{8}$
$\frac{3}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	1	2	$1\frac{1}{2}$	$\frac{3}{16}$
$\frac{5}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	$1\frac{1}{8}$	2	2	$\frac{3}{16}$
$\frac{7}{8}$	$1\frac{1}{8}$	$\frac{5}{8}$	$1\frac{3}{8}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$\frac{1}{4}$
$1\frac{1}{8}$	$1\frac{3}{8}$	$\frac{5}{8}$	$1\frac{3}{8}$	$2\frac{1}{4}$	3	$\frac{1}{4}$
$1\frac{3}{8}$	$1\frac{5}{8}$	$\frac{3}{4}$	$1\frac{5}{8}$	$2\frac{3}{4}$	$3\frac{1}{2}$	$\frac{1}{4}$
$1\frac{5}{8}$	2	$\frac{3}{4}$	$1\frac{7}{8}$	$3\frac{1}{8}$	4	$\frac{1}{4}$
2	$2\frac{1}{4}$	$\frac{3}{4}$	2	$3\frac{1}{4}$	$4\frac{1}{2}$	$\frac{1}{4}$
$2\frac{1}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$	$2\frac{1}{8}$	$3\frac{3}{8}$	$4\frac{3}{4}$	$\frac{1}{4}$
$2\frac{1}{2}$	$2\frac{3}{4}$	$\frac{3}{4}$	$2\frac{1}{4}$	$3\frac{1}{2}$	5	$\frac{1}{4}$
$2\frac{3}{4}$	3	$\frac{3}{4}$	$2\frac{3}{8}$	$3\frac{5}{8}$	$5\frac{1}{4}$	$\frac{1}{4}$



Snap Gages for Lengths

Where standard adjustable gages cannot conveniently be used
(Dimensions in Inches)

Nominal Size		A	B	C	D	E	F	G	H	K	L	Thickness
Over	To											M

TOLERANCES FOR PLAIN PLUG, RING, AND SNAP GAGES

Size of gage, inches	Tolerances for "go" gages				Class Z		Tolerances for "not go" gages	
	Class X		Class Y					
	Limits, inch	Tol., inch	Limits, inch	Tol., inch	Limits, inch	Tol., inch	Limits, inch	Tol., inch
0 2 incl.	0.0000	0.0001	0.0001	0.0001	0.0002	0.0001	0.0000	0.000
	0.0001	.....	0.0002	.....	0.0003	.....	0.0001	.....
2-4	0.0000	0.0002	0.0001	0.0002	0.0003	0.0002	0.0000	0.000
	0.0002	.....	0.0003	.....	0.0005	.....	0.0002	.....
4 6	0.0000	0.0003	0.0002	0.0003	0.0005	0.0003	0.0000	0.000
	0.0003	.....	0.0005	.....	0.0008	.....	0.0008	.....
6-8	0.0000	0.0004	0.0003	0.0004	0.0006	0.0004	0.0000	0.000
	0.0004	.....	0.0007	.....	0.0001	.....	0.0004	.....

GRINDING LIMITS FOR CYLINDRICAL PIECES

It is Brown & Sharpe practice to consider the hole as being standard, and the limits shown below are based on the standard hole. The grinding limits for holes apply to hardened pieces The holes in soft pieces are chucked to standard diameter. It i possible that where both parts are hardened, closer limits may b necessary, assuming the parts are to be assembled without fitting.

RUNNING FITS—ORDINARY SPEEDS

These limits are satisfactory for shafts running under 600 R.P.M and under ordinary working conditions. Spindles for all purpose are to be considered as special cases.

To ½-inch diameter, inc..... 0.0005 to 0.001 Sma
To 1-inch diameter, inc..... 0.00075 to 0.0015 Sma
To 2-inch diameter, inc..... 0.0015 to 0.0025 Sma
To 3½-inch diameter, inc..... 0.002 to 0.003 Sma
To 6-inch diameter, inc..... 0.0025 to 0.004 Sma

RUNNING FITS—HIGH SPEED, HEAVY PRESSURE AND ROCKER SHAFT

These limits are satisfactory for shafts running more than 60 R.P.M. and where the working conditions are severe. Spindles fo all purposes are to be considered as special cases.

To ½-inch diameter, inc..... 0.0005 to 0.001 Sma
To 1-inch diameter, inc..... 0.001 to 0.002 Sma
To 2-inch diameter, inc..... 0.002 to 0.003 Sma
To 3½-inch diameter, inc..... 0.003 to 0.004 Sma
To 6-inch diameter, inc..... 0.004 to 0.005 Sma

SLIDING FITS

These limits are for shafts where a gear, clutch or other simila part slides on it continuously while the machine is in operation These limits are the same as for "Running Fits, Ordinary Speeds.

To ½-inch diameter, inc..... 0.0005 to 0.001 Sma
To 1-inch diameter, inc..... 0.00075 to 0.0015 Sma
To 2-inch diameter, inc..... 0.0015 to 0.0025 Sma
To 3½-inch diameter, inc..... 0.002 to 0.003 Sma
To 6-inch diameter, inc..... 0.0025 to 0.004 Sma

STANDARD FITS—WHERE THE LOAD IS NOT HEAVY AND WHERE THE PART IS KEYED TO THE SHAFT AND CLAMPED ENDWISE WITH A NUT

These limits are suitable for light service only and where no fitting is to be done.

To ½-inch diameter, inc.	Standard to 0.00025		Small
To 3½-inch diameter, inc.	Standard to 0.0005		Small
To 6-inch diameter, inc.	Standard to 0.00075		Small

These limits are to be used where it is desirable or essential that the parts fit together without play, and still be put together or taken apart without difficulty. Some fitting may be required and also some selecting may be necessary to attain the proper results.

To ½-inch diameter, inc.	Standard to 0.00025		Large
To 3½-inch diameter, inc	Standard to 0.0005		Large
To 6-inch diameter, inc.	Standard to 0.00075		Large

DRIVING FITS

For use where parts must fit tightly and where the location of the parts is such that they could not be put together if the drive was too great. These limits will apply where the assembly is permanent.

To ½-inch diameter, inc.	Standard to 0.00025		Large
To 1-inch diameter, inc.	0.0025	to 0.0005	Large
To 2-inch diameter, inc.	0.0005	to 0.00075	Large
To 6-inch diameter, inc.	0.0005	to 0.001	Large

DRIVING FITS

To be used where the assembly is permanent and the duty severe, and where there is room for the handling and driving of the parts.

To 2-inch diameter, inc.	0.0005	to 0.001	Large
To 3½-inch diameter, inc.	0.00075	to 0.00125	Large
To 6-inch diameter, inc.	0.001	to 0.0015	Large

FORCING FITS

These limits may be used where parts are not expected to be taken apart and where service is very severe. This assembling is done under the arbor press for the smaller parts and under the hydraulic press for larger parts.

The method of forcing the parts together and the length of the parts will have influence on how large to leave the shaft.

To ½-inch diameter, inc.	0.00075	to 0.001	Large
To 1-inch diameter, inc.	0.001	to 0.002	Large
To 2-inch diameter, inc.	0.002	to 0.003	Large
To 3½-inch diameter, inc.	0.003	to 0.004	Large
To 6-inch diameter, inc.	0.004	to 0.005	Large

SHRINKING FITS—FOR PIECES TO TAKE HARDENED SHELLS ⅜ INCH THICK AND LESS

To 1-inch diameter, inc.	0.00025	to 0.0005	Large
To 2-inch diameter, inc.	0.0005	to 0.00075	Large
To 3½-inch diameter, inc.	0.0005	to 0.001	Large
To 6-inch diameter, inc.	0.001	to 0.0015	Large

SHRINKING FITS—FOR PIECES TO TAKE SHELLS, ETC., HAVING A THICKNESS OF MORE THAN $\frac{3}{8}$ INCH

To $\frac{1}{2}$-inch diameter, inc.....	0.0005 to 0.001	Large
To 1-inch diameter, inc.....	0.001 to 0.002	Large
To 2-inch diameter, inc.....	0.002 to 0.003	Large
To $3\frac{1}{2}$-inch diameter, inc.....	0.003 to 0.004	Large
To 6-inch diameter, inc.....	0.004 to 0.005	Large

GRINDING LIMITS FOR HOLES

To 2-inch diameter, inc.....	Standard to 0.0005	Large
To $3\frac{1}{2}$-inch diameter, inc.....	Standard to 0.00075	Large
To 6-inch diameter, inc.....	Standard to 0.001	Large

BRITISH ENGINEERING STANDARDS ASSOCIATION[1]

British Standard Limits and Fits for Engineering

The basis of the tables herewith being a hole basis, the limiting dimensions of any hole of a particular quality and size remain unchanged, and varieties of fit are obtained by varying the actual dimensions of the shaft. The Association recognises that exceptions to this rule are necessary in certain classes of work.

Table 1 gives both unilateral and bilateral limits of tolerance for holes. In the unilateral system, the nominal size is the low limit of the hole; in the bilateral system, the nominal size lies between the high and low limits of the hole. The Association recommends the use of the unilateral system as applied to cylindrical mating surfaces in cases where it does not conflict with predominating present practice.

Table 2 gives the recommended limits of tolerance for a standard series of graduated shafts suitable for pairing with either the unilateral or bilateral holes. Table 3 shows the numerical values of the limits of fit resulting from the assembly of any one of the standard shafts in a particular unilateral hole and a particular bilateral hole. The particular holes chosen for these numerical examples are identified by the symbols **U** and **X** (Table 1) respectively, and they have been selected because the tolerances on these holes are those most commonly employed. The numerical values of the limits of fit resulting from the assembly of the standard shafts in any of the other holes specified in the tables can be arrived at by simple arithmetical calculation.

The effect of transferring any standard shaft from a bilateral hole to a unilateral hole tends either to increase the clearance or to decrease the interference; in short, it makes the fit easier.

Table 1 provides four standard grades of workmanship for holes, in which **B** (unilateral) and **K** (bilateral) holes represent the most accurate grade, while **U** (unilateral) and **X** (bilateral) holes represent those most commonly employed. Unilateral holes **V, W,** and bilateral holes **Y, Z,** have larger tolerances.

Table 1 also provides for the use of three holes **A, G, H,** each with two positive limits of tolerance. These are called oversize holes. They are common to both the unilateral and bilateral systems, and are included in the tables to meet exceptional conditions.

[1] Permission of British Engineering Standards Association.

The range of the tables is from 0 to approximately 25 inches (635 millimeters) in diameter. The nominal sizes are specified in ranges and the length of each range is such that at each change of range the tolerance increase on U and X holes is two ten-thousandths of an inch.

The table of shafts, which is common to the unilateral and bilateral systems, provides for a series of fourteen different fits with reference to any particular hole by progressively changing the disposition of the tolerance in relation to the nominal size. The tolerance itself remains unchanged for all shafts in the table from F to M inclusive. These shafts are of the same grade of workmanship as a B hole. Shafts Q, R, S, T, TT are given increasing tolerances because they are all considerably undersize and, therefore, provide increasing amounts of clearance when assembled in any hole.

The range of fits provided by the full series of shafts is divided into three main classes, which are defined on the diagram as Interference, Transition and Clearance Fits. These terms are recommended for use when specifying a class of fit. Terms such as push fit, etc., which are in common use but have no numerically exact meaning, are not recommended, but their approximate application to the table has been indicated in the diagram in order that the new standards may be more readily applied to existing practice. When the exact nature of a fit has to be named, it is recommended that the symbols of the hole and shaft be used in combination, *e.g.*, UR, and marked on the assembly drawing in this form. The drawing of the hole and the drawing of the shaft can then be marked U and R respectively in combination with the nominal size, *e.g.*, in reference to the nominal size $1\frac{3}{4}$, $1\frac{3}{4}$ inches U, $1\frac{3}{4}$ inches R, or the limits of tolerance can be specified in figures if preferred.

The Association recommends, in the interests of uniformity and lucid terminology, that where different classes of fit have to be described in general terms, the following definitions should be employed:

(*a*) "*Clearance fit*" where there is a positive allowance between the largest possible shaft and the smallest possible hole.

(*b*) "*Interference fit*" where there is a negative allowance (obstruction) between the largest hole and the smallest shaft, the shaft being larger than the hole.

(*c*) "*Transition fit*" covering cases between (*a*) and (*b*), *i.e.*, cases in which the limits admit of either clearance or interference fits being obtained.

Size Multiplier *m* and Range Factor *r*.—Values of *m*, the size multiplier, for nominal sizes from Zero to 25.29 inches (632.49 millimeters) and *r*, the range factor, are given respectively in the first column and the last line of the tables.

The limit values in the tables are found by multiplying together these quantities *m* and *r*, odd half-ten-thousandths being eliminated by subtracting such odd amounts from the products in which they occur, negative products thus becoming more negative.

EXAMPLE 1.—To find the limits for a $2\frac{1}{4}$-inch U hole.

The value of *m* corresponding with $2\frac{1}{4}$-inches is 8; see table on page 545.

The value of r for the high limit of U = 2 (in ten thousandths of an inch).

The value of r for the low limit of U = 0. Hence required limits are + 0.0016 inch and + 0.

EXAMPLE 2.—To find the limits for a $6\frac{1}{4}$-inch X hole.

The value of m for $6\frac{1}{4}$-inches = 12.

The value of r for the high limit of X = + 1.

The value of r for the low limit of X = − 1.

Hence required limits for ± 0.0012.

EXAMPLE 3.—Assuming that the minimum hole passed by a plug limit gauge be 0.0003 inch greater than the tabular low limit for a $4\frac{1}{2}$-inch X hole, what actual clearance will such a hole afford a $4\frac{1}{2}$-inch R shaft when the latter is only 0.0002 inch below its tabular high limit?

The value of m for $4\frac{1}{2}$ inches = 11.

The value of r for the low limit of X = − 1.

The values of r for R = −0.3 and −0.5.

Hence minimum hole the gauge will

accept = $4\frac{1}{2}$ inches − 0.0011 inch
+ 0.0003 inch
= $4\frac{1}{2}$ inches − 0.0008 inch.

Actual size of shaft = $4\frac{1}{2}$ inches − 0.0033 inch − 0.0002 inch.
= $4\frac{1}{2}$ inches − 0.0035 inch.

Hence clearance = 0.0035 inch − 0.0008 inch = 0.0027 inch; which is (0.0003 + 0.0002) or 0.0005 inch greater than the figure given for minimum clearance in the Table of Fits, page 547.

Table 1.—British Standard Limits and Fits for Engineering

Unilateral, Bilateral and Oversize Holes

BRITISH SYSTEM—INCHES

THE USE OF THE UNILATERAL SYSTEM AS APPLIED TO CYLINDRICAL MATING SURFACES IS RECOMMENDED IN CASES WHERE IT DOES NOT CONFLICT WITH PREDOMINATING PRESENT PRACTICE

(All dimensions except nominal sizes are expressed in thousandths of an inch)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Size Multiplier	Nominal Sizes	Unilateral Holes (In which the low limit of the hole is nominal size.)								Bilateral Holes (In which the nominal size of the hole lies between the high and low limits.)			
		B		U		V		W		K		X	
m	Inches	H	L	H	L	H	L	H	L	H	L	H	L
3	0– 0.29	+0.3	0	+0.6	0	+1.2	0	+ 2.4	0	+0.1	−0.2	+0.3	−0.3
4	0.3– 0.59	+0.4	0	+0.8	0	+1.6	0	+ 3.2	0	+0.2	−0.2	+0.4	−0.4
5	0.6– 0.99	+0.5	0	+1.0	0	+2.0	0	+ 4.0	0	+0.2	−0.3	+0.5	−0.5
6	1.0– 1.49	+0.6	0	+1.2	0	+2.4	0	+ 4.8	0	+0.3	−0.3	+0.6	−0.6
7	1.5– 2.09	+0.7	0	+1.4	0	+2.8	0	+ 5.6	0	+0.3	−0.4	+0.7	−0.7
8	2.1– 2.79	+0.8	0	+1.6	0	+3.2	0	+ 6.4	0	+0.4	−0.4	+0.8	−0.8
9	2.8– 3.59	+0.9	0	+1.8	0	+3.6	0	+ 7.2	0	+0.4	−0.5	+0.9	−0.9
10	3.6– 4.49	+1.0	0	+2.0	0	+4.0	0	+ 8.0	0	+0.5	−0.5	+1.0	−1.0
11	4.5– 5.49	+1.1	0	+2.2	0	+4.4	0	+ 8.8	0	+0.5	−0.6	+1.1	−1.1
12	5.5– 6.59	+1.2	0	+2.4	0	+4.8	0	+ 9.6	0	+0.6	−0.6	+1.2	−1.2
13	6.6– 7.79	+1.3	0	+2.6	0	+5.2	0	+10.4	0	+0.6	−0.7	+1.3	−1.3
14	7.8 –9.09	+1.4	0	+2.8	0	+5.6	0	+11.2	0	+0.7	−0.7	+1.4	−1.4
15	9.1–10.49	+1.5	0	+3.0	0	+6.0	0	+12.0	0	+0.7	−0.8	+1.5	−1.5
16	10.5–11.99	+1.6	0	+3.2	0	+6.4	0	+12.8	0	+0.8	−0.8	+1.6	−1.6
17	12.0–13.59	+1.7	0	+3.4	0	+6.8	0	+13.6	0	+0.8	−0.9	+1.7	−1.7
18	13.6–15.29	+1.8	0	+3.6	0	+7.2	0	+14.4	0	+0.9	−0.9	+1.8	−1.8
19	15.3–17.09	+1.9	0	+3.8	0	+7.6	0	+15.2	0	+0.9	−1.0	+1.9	−1.9
20	17.1–18.99	+2.0	0	+4.0	0	+8.0	0	+16.0	0	+1.0	−1.0	+2.0	−2.0
21	19.0–20.99	+2.1	0	+4.2	0	+8.4	0	+16.8	0	+1.0	−1.1	+2.1	−2.1
22	21.0–23.09	+2.2	0	+4.4	0	+8.8	0	+17.6	0	+1.1	−1.1	+2.2	−2.2
23	23.1–25.29	+2.3	0	+4.6	0	+9.2	0	+18.4	0	+1.1	−1.2	+2.3	−2.3
Range Factor, r		+0.1	0	+0.2	0	+0.4	0	+ 0.8	0	+0.05	−0.05	+0.1	−0.1

TABLE 1.—*Continued.*

1	2	15	16	17	18	19	20	21	22	23	24	25	26
Size Multiplier	Nominal Sizes	Bilateral Holes (In which the nominal size of the hole lies between the high and low limits.)				Oversize Holes (In which the low limit of the hole is larger than the nominal size.)						Non-Mating Holes and Shafts	
		Y		Z		A		G		H		J	
m	Inches	H	L	H	L	H	L	H	L	H	L	H	L
3	0– 0.29	+0.6	−0.6	+1.2	−1.2	+1.2	+0.6	+ 1.8	+1.2	+ 2.4	+ 1.8	+ 3.0	− 3.0
4	0.3– 0.59	+0.8	−0.8	+1.6	−1.6	+1.6	+0.8	+ 2.4	+1.6	+ 3.2	+ 2.4	+ 4.0	− 4.0
5	0.6– 0.99	+1.0	−1.0	+2.0	−2.0	+2.0	+1.0	+ 3.0	+2.0	+ 4.0	+ 3.0	+ 5.0	− 5.0
6	1.0– 1.49	+1.2	−1.2	+2.4	−2.4	+2.4	+1.2	+ 3.6	+2.4	+ 4.8	+ 3.6	+ 6.0	− 6.0
7	1.5– 2.09	+1.4	−1.4	+2.8	−2.8	+2.8	+1.4	+ 4.2	+2.8	+ 5.6	+ 4.2	+ 7.0	− 7.0
8	2.1– 2.79	+1.6	−1.6	+3.2	−3.2	+3.2	+1.6	+ 4.8	+3.2	+ 6.4	+ 4.8	+ 8.0	− 8.0
9	2.8– 3.59	+1.8	−1.8	+3.6	−3.6	+3.6	+1.8	+ 5.4	+3.6	+ 7.2	+ 5.4	+ 9.0	− 9.0
10	3.6– 4.49	+2.0	−2.0	+4.0	−4.0	+4.0	+2.0	+ 6.0	+4.0	+ 8.0	+ 6.0	+10.0	−10.0
11	4.5– 5.49	+2.2	−2.2	+4.4	−4.4	+4.4	+2.2	+ 6.6	+4.4	+ 8.8	+ 6.6	+11.0	−11.0
12	5.5– 6.59	+2.4	−2.4	+4.8	−4.8	+4.8	+2.4	+ 7.2	+4.8	+ 9.6	+ 7.2	+12.0	−12.0
13	6.6– 7.79	+2.6	−2.6	+5.2	−5.2	+5.2	+2.6	+ 7.8	+5.2	+10.4	+ 7.8	+13.0	−13.0
14	7.8 –9.09	+2.8	−2.8	+5.6	−5.6	+5.6	+2.8	+ 8.4	+5.6	+11.2	+ 8.4	+14.0	−14.0
15	9.1–10.49	+3.0	−3.0	+6.0	−6.0	+6.0	+3.0	+ 9.0	+6.0	+12.0	+ 9.0	+15.0	−15.0
16	10.5–11.99	+3.2	−3.2	+6.4	−6.4	+6.4	+3.2	+ 9.6	+6.4	+12.8	+ 9.6	+16.0	−16.0
17	12.0–13.59	+3.4	−3.4	+6.8	−6.8	+6.8	+3.4	+10.2	+6.8	+13.6	+10.2	+17.0	−17.0
18	13.6–15.29	+3.6	−3.6	+7.2	−7.2	+7.2	+3.6	+10.8	+7.2	+14.4	+10.8	+18.0	−18.0
19	15.3–17.09	+3.8	−3.8	+7.6	−7.6	+7.6	+3.8	+11.4	+7.6	+15.2	+11.4	+19.0	−19.0
20	17.1–18.99	+4.0	−4.0	+8.0	−8.0	+8.0	+4.0	+12.0	+8.0	+16.0	+12.0	+20.0	−20.0
21	19.0–20.99	+4.2	−4.2	+8.4	−8.4	+8.4	+4.2	+12.6	+8.4	+16.8	+12.6	+21.0	−21.0
22	21.0–23.09	+4.4	−4.4	+8.8	−8.8	+8.8	+4.4	+13.2	+8.8	+17.6	+13.2	+22.0	−22.0
23	23.1–25.29	+4.6	−4.6	+9.2	−9.2	+9.2	+4.6	+13.8	+9.2	+18.4	+13.8	+23.0	−23.0
Range Factor, r		+0.2	−0.2	+0.4	−0.4	+0.4	+0.2	+ 0.6	+0.4	+ 0.8	+ 0.6	+ 1.0	− 1.0

H = High limit of tolerance. **L** = Low limit of tolerance. The sign + or — below the symbols **H** and **L** indicates whether the limits are positive or negative.

TABLE 2.—BRITISH STANDARD LIMITS AND FITS FOR ENGINEERING
STANDARD SHAFTS
FOR USE WITH EITHER UNILATERAL, BILATERAL OR OVERSIZE HOLES
BRITISH SYSTEM—INCHES
THE USE OF THE UNILATERAL SYSTEM AS APPLIED TO CYLINDRICAL MATING SURFACES IS RECOMMENDED IN CASES WHERE IT DOES NOT CONFLICT WITH PREDOMINATING PRESENT PRACTICE
(All dimensions except nominal sizes are expressed in thousandths of an inch)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Size Multiplier	Nominal Sizes	F		E		D		C		B		K		L	
m	Inches	H	L	H	L	H	L	H	L	H	L	H	L	H	L
3	0– 0.29	+1.2	+0.9	+0.9	+0.6	+0.6	+0.3	−0.4	+0.1	−0.3	0	+0.1	−0.2	0	−0.3
4	0.3– 0.59	+1.6	+1.2	+1.2	+0.8	+0.8	+0.4	+0.6	+0.2	+0.4	0	+0.2	−0.2	0	−0.4
5	0.6– 0.99	+2.0	+1.5	+1.5	+1.0	+1.0	+0.5	+0.7	+0.2	+0.5	0	+0.2	−0.3	0	−0.5
6	1.0– 1.49	+2.4	+1.8	+1.8	+1.2	+1.2	+0.6	+0.9	+0.3	+0.6	0	+0.3	−0.3	0	−0.6
7	1.5– 2.09	+2.8	+2.1	+2.1	+1.4	+1.4	+0.7	+1.0	+0.3	+0.7	0	+0.3	−0.4	0	−0.7
8	2.1– 2.79	+3.2	+2.4	+2.4	+1.6	+1.6	+0.8	+1.2	+0.4	+0.8	0	+0.4	−0.4	0	−0.8
9	2.8– 3.59	+3.6	+2.7	+2.7	+1.8	+1.8	+0.9	+1.3	+0.4	+0.9	0	+0.4	−0.5	0	−0.9
10	3.6– 4.49	+4.0	+3.0	+3.0	+2.0	+2.0	+1.0	+1.5	+0.5	+1.0	0	+0.5	−0.5	0	−1.0
11	4.5– 5.49	+4.4	+3.3	+3.3	+2.2	+2.2	+1.1	+1.6	+0.5	+1.1	0	+0.5	−0.6	0	−1.1
12	5.5– 6.59	+4.8	+3.6	+3.6	+2.4	+2.4	+1.2	+1.8	+0.6	+1.2	0	+0.6	−0.6	0	−1.2
13	6.6– 7.79	+5.2	+3.9	+3.9	+2.6	+2.6	+1.3	+1.9	+0.6	+1.3	0	+0.6	−0.7	0	−1.3
14	7.8– 9.09	+5.6	+4.2	+4.2	+2.8	+2.8	+1.4	+2.1	+0.7	+1.4	0	+0.7	−0.7	0	−1.4
15	9.1–10.49	+6.0	+4.5	+4.5	+3.0	+3.0	+1.5	+2.2	+0.7	+1.5	0	+0.7	−0.8	0	−1.5
16	10.5–11.99	+6.4	+4.8	+4.8	+3.2	+3.2	+1.6	+2.4	+0.8	+1.6	0	+0.8	−0.8	0	−1.6
17	12.0–13.59	+6.8	+5.1	+5.1	+3.4	+3.4	+1.7	+2.5	+0.8	+1.7	0	+0.8	−0.9	0	−1.7
18	13.6–15.29	+7.2	+5.4	+5.4	+3.6	+3.6	+1.8	+2.7	+0.9	+1.8	0	+0.9	−0.9	0	−1.8
19	15.3–17.09	+7.6	+5.7	+5.7	+3.8	+3.8	+1.9	+2.8	+0.9	+1.9	0	+0.9	−1.0	0	−1.9
20	17.1–18.99	+8.0	+6.0	+6.0	+4.0	+4.0	+2.0	+3.0	+1.0	+2.0	0	+1.0	−1.0	0	−2.0
21	19.0–20.99	+8.4	+6.3	+6.3	+4.2	+4.2	+2.1	+3.1	+1.0	+2.1	0	+1.0	−1.1	0	−2.1
22	21.0–23.09	+8.8	+6.6	+6.6	+4.4	+4.4	+2.2	+3.3	+1.1	+2.2	0	+1.1	−1.1	0	−2.2
23	23.1–25.29	+9.2	+6.9	+6.9	+4.6	+4.6	+2.3	+3.4	+1.1	+2.3	0	+1.1	−1.2	0	−2.3
Range Factor, *r*		+0.4	+0.3	+0.3	+0.2	+0.2	+0.1	+0.15	+0.05	+0.1	0	+0.05	−0.05	0	−0.1

TABLE 2.—*Continued.*

1	2	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Size Multiplier	Nominal Sizes	P		M		Q		R		S		T		TT	
m	Inches	H	L	H	L	H	L	H	L	H	L	H	L	H	L
3	0– 0.29	−0.2	−0.5	−0.3	−0.6	−0.5	−0.9	−0.9	− 1.5	− 1.5	− 2.4	− 2.4	− 3.6	− 3.6	− 6.0
4	0.3– 0.59	−0.2	−0.6	−0.4	−0.8	−0.6	−1.2	−1.2	− 2.0	− 2.0	− 3.2	− 3.2	− 4.8	− 4.8	− 8.0
5	0.6– 0.99	−0.3	−0.8	−0.5	−1.0	−0.8	−1.5	−1.5	− 2.5	− 2.5	− 4.0	− 4.0	− 6.0	− 6.0	− 10.0
6	1.0– 1.49	−0.3	−0.9	−0.6	−1.2	−0.9	−1.8	−1.8	− 3.0	− 3.0	− 4.8	− 4.8	− 7.2	− 7.2	− 12.0
7	1.5– 2.09	−0.4	−1.1	−0.7	−1.4	−1.1	−2.1	−2.1	− 3.5	− 3.5	− 5.6	− 5.6	− 8.4	− 8.4	− 14.0
8	2.1– 2.79	−0.4	−1.2	−0.8	−1.6	−1.2	−2.4	−2.4	− 4.0	− 4.0	− 6.4	− 6.4	− 9.6	− 9.6	− 16.0
9	2.8– 3.59	−0.5	−1.4	−0.9	−1.8	−1.4	−2.7	−2.7	− 4.5	− 4.5	− 7.2	− 7.2	− 10.8	− 10.8	− 18.0
10	3.6– 4.49	−0.5	−1.5	−1.0	−2.0	−1.5	−3.0	−3.0	− 5.0	− 5.0	− 8.0	− 8.0	− 12.0	− 12.0	− 20.0
11	4.5– 5.49	−0.6	−1.7	−1.1	−2.2	−1.7	−3.3	−3.3	− 5.5	− 5.5	− 8.8	− 8.8	− 13.2	− 13.2	− 22.0
12	5.5– 6.59	−0.6	−1.8	−1.2	−2.4	−1.8	−3.6	−3.6	− 6.0	− 6.0	− 9.6	− 9.6	− 14.4	− 14.4	− 24.0
13	6.6– 7.79	−0.7	−2.0	−1.3	−2.6	−2.0	−3.9	−3.9	− 6.5	− 6.5	− 10.4	− 10.4	− 15.6	− 15.6	− 26.0
14	7.8– 9.09	−0.7	−2.1	−1.4	−2.8	−2.1	−4.2	−4.2	− 7.0	− 7.0	− 11.2	− 11.2	− 16.8	− 16.8	− 28.0
15	9.1–10.49	−0.8	−2.3	−1.5	−3.0	−2.3	−4.5	−4.5	− 7.5	− 7.5	− 12.0	− 12.0	− 18.0	− 18.0	− 30.0
16	10.5–11.99	−0.8	−2.4	−1.6	−3.2	−2.4	−4.8	−4.8	− 8.0	− 8.0	− 12.8	− 12.8	− 19.2	− 19.2	− 32.0
17	12.0–13.59	−0.9	−2.6	−1.7	−3.4	−2.6	−5.1	−5.1	− 8.5	− 8.5	− 13.6	− 13.6	− 20.4	− 20.4	− 34.0
18	13.6–15.29	−0.9	−2.7	−1.8	−3.6	−2.7	−5.4	−5.4	− 9.0	− 9.0	− 14.4	− 14.4	− 21.6	− 21.6	− 36.0
19	15.3–17.09	−1.0	−2.9	−1.9	−3.8	−2.9	−5.7	−5.7	− 9.5	− 9.5	− 15.2	− 15.2	− 22.8	− 22.8	− 38.0
20	17.1–18.99	−1.0	−3.0	−2.0	−4.0	−3.0	−6.0	−6.0	− 10.0	− 10.0	− 16.0	− 16.0	− 24.0	− 24.0	− 40.0
21	19.0–20.99	−1.1	−3.2	−2.1	−4.2	−3.2	−6.3	−6.3	− 10.5	− 10.5	− 16.8	− 16.8	− 25.2	− 25.2	− 42.0
22	21.0–23.00	−1.1	−3.3	−2.2	−4.4	−3.3	−6.6	−6.6	− 11.0	− 11.0	− 17.6	− 17.6	− 26.4	− 26.4	− 44.0
23	23.1–25.29	−1.2	−3.5	−2.3	−4.6	−3.5	−6.9	−6.9	− 11.5	− 11.5	− 18.4	− 18.4	− 27.6	− 27.6	− 46.0
Range Factor, *r*		−0.05	−0.15	−0.1	−0.2	−0.15	−0.3	−0.3	− 0.5	− 0.5	− 0.8	− 0.8	− 1.2	− 1.2	− 2.0

H = High limit of tolerance. **L** = Low limit of tolerance. The sign + or — below the symbols **H** and **L** indicates whether the limits are positive or negative.

TABLE 3.—BRITISH STANDARD LIMITS AND FITS FOR ENGINEERING FITS OF STANDARD SHAFTS IN "U" AND "X" HOLES

BRITISH SYSTEM—INCHES

The use of the unilateral system as applied to cylindrical mating surfaces is recommended in cases where it does not conflict with predominating present practice

(All dimensions except nominal sizes are expressed in thousandths of an inch)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Size Multiplier	Nominal Sizes	STANDARD SHAFTS IN UNILATERAL "U" HOLES													
m	Inches	UF	UE	UD	UC	UB	UK	UL	UP	UM	UQ	UR	US	UT	UTT
3	0– 0.29	−1.2	−0.9	−0.6	−0.4	−0.3	−0.1	0	+0.2	+0.3	+ 0.5	+ 0.9	+ 1.5	+ 2.4	+ 3.6
		−0.3	0	+0.3	+0.5	+0.6	+0.8	+0.9	+1.1	+1.2	+ 1.5	+ 2.1	+ 3.0	+ 4.2	+ 6.6
4	0.3– 0.59	−1.6	−1.2	−0.8	−0.6	−0.4	−0.2	0	+0.2	+0.4	+ 0.6	+ 1.2	+ 2.0	+ 3.2	+ 4.8
		−0.4	0	+0.4	+0.6	+0.8	+1.0	+1.2	+1.4	+1.6	+ 2.0	+ 2.8	+ 4.0	+ 5.6	+ 8.8
5	0.6– 0.99	−2.0	−1.5	−1.0	−0.7	−0.5	−0.2	0	+0.3	+0.5	+ 0.8	+ 1.5	+ 2.5	+ 4.0	+ 6.0
		−0.5	0	+0.5	+0.8	+1.0	+1.3	+1.5	+1.8	+2.0	+ 2.5	+ 3.5	+ 5.0	+ 7.0	+11.0
6	1.0– 1.49	−2.4	−1.8	−1.2	−0.9	−0.6	−0.3	0	+0.3	+0.6	+ 0.9	+ 1.8	+ 3.0	+ 4.8	+ 7.2
		−0.6	0	+0.6	+0.9	+1.2	+1.5	+1.8	+2.1	+2.4	+ 3.0	+ 4.2	+ 6.0	+ 8.4	+13.2
7	1.5– 2.09	−2.8	−2.1	−1.4	−1.0	−0.7	−0.3	0	+0.4	+0.7	+ 1.1	+ 2.1	+ 3.5	+ 5.6	+ 8.4
		−0.7	0	+0.7	+1.1	+1.4	+1.8	+2.1	+2.5	+2.8	+ 3.5	+ 4.9	+ 7.0	+ 9.8	+15.4
8	2.1– 2.79	−3.2	−2.4	−1.6	−1.2	−0.8	−0.4	0	+0.4	+0.8	+ 1.2	+ 2.4	+ 4.0	+ 6.4	+ 9.6
		−0.8	0	+0.8	+1.2	+1.6	+2.0	+2.4	+2.8	+3.2	+ 4.0	+ 5.6	+ 8.0	+11.2	+17.6
9	2.8– 3.59	−3.6	−2.7	−1.8	−1.3	−0.9	−0.4	0	+0.5	+0.9	+ 1.4	+ 2.7	+ 4.5	+ 7.2	+10.8
		−0.9	0	+0.9	+1.4	+1.8	+2.3	+2.7	+3.2	+3.6	+ 4.5	+ 6.3	+ 9.0	+12.6	+19.8
10	3.6– 4.49	−4.0	−3.0	−2.0	−1.5	−1.0	−0.5	0	+0.5	+1.0	+ 1.5	+ 3.0	+ 5.0	+ 8.0	+12.0
		−1.0	0	+1.0	+1.5	+2.0	+2.5	+3.0	+3.5	+4.0	+ 5.0	+ 7.0	+10.0	+14.0	+22.0
11	4.5– 5.49	−4.4	−3.3	−2.2	−1.6	−1.1	−0.5	0	+0.6	+1.1	+ 1.7	+ 3.3	+ 5.5	+ 8.8	+13.2
		−1.1	0	+1.1	+1.7	+2.2	+2.8	+3.3	+3.9	+4.4	+ 5.5	+ 7.7	+11.0	+15.4	+24.2

TABLE—3. *Continued.*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Size Multiplier	Nominal Sizes	STANDARD SHAFTS IN UNILATERAL "U" HOLES													
m	Inches	UF	UE	UD	UC	UB	UK	UL	UP	UM	UQ	UR	US	UT	UTT
12	5.5– 6.59	−4.8 −1.2	−3.6 0	−2.4 +1.2	−1.8 +1.8	−1.2 +2.4	−0.6 +3.0	0 +3.6	+0.6 +4.2	+1.2 +4.8	+ 1.8 + 6.0	+ 3.6 + 8.4	+ 6.0 +12.0	+ 9.6 +16.8	+14.4 +26.4
13	6.6– 7.79	−5.2 −1.3	−3.9 0	−2.6 +1.3	−1.9 +2.0	−1.3 +2.6	−0.6 +3.3	0 +3.9	+0.7 +4.6	+1.3 +5.2	+ 2.0 + 6.5	+ 3.9 + 9.1	+ 6.5 +13.0	+10.4 +18.2	+15.6 +28.6
14	7.8– 9.09	−5.6 −1.4	−4.2 0	−2.8 +1.4	−2.1 +2.1	−1.4 +2.8	−0.7 +3.5	0 +4.2	+0.7 +4.9	+1.4 +5.6	+ 2.1 + 7.0	+ 4.2 + 9.8	+ 7.0 +14.0	+11.2 +19.6	+16.8 +30.8
15	9.1–10.49	−6.0 −1.5	−4.5 0	−3.0 +1.5	−2.2 +2.3	−1.5 +3.0	−0.7 +3.8	0 +4.5	+0.8 +5.3	+1.5 +6.0	+ 2.3 + 7.5	+ 4.5 +10.5	+ 7.5 +15.0	+12.0 +21.0	+18.0 +33.0
16	10.5–11.99	−6.4 −1.6	−4.8 0	−3.2 +1.6	−2.4 +2.4	−1.6 +3.2	−0.8 +4.0	0 +4.8	+0.8 +5.6	+1.6 +6.4	+ 2.4 + 8.0	+ 4.8 +11.2	+ 8.0 +16.0	+12.8 +22.4	+19.2 +35.2
17	12.0–13.59	−6.8 −1.7	−5.1 0	−3.4 +1.7	−2.5 +2.6	−1.7 +3.4	−0.8 +4.3	0 +5.1	+0.9 +6.0	+1.7 +6.8	+ 2.6 + 8.5	+ 5.1 +11.9	+ 8.5 +17.0	+13.6 +23.8	+20.4 +37.4
18	13.6–15.29	−7.2 −1.8	−5.4 0	−3.6 +1.8	−2.7 +2.7	−1.8 +3.6	−0.9 +4.5	0 +5.4	+0.9 +6.3	+1.8 +7.2	+ 2.7 + 9.0	+ 5.4 +12.6	+ 9.0 +18.0	+14.4 +25.2	+21.6 +39.6
19	15.3–17.09	−7.6 −1.9	−5.7 0	−3.8 +1.9	−2.8 +2.9	−1.9 +3.8	−0.9 +4.8	0 +5.7	+1.0 +6.7	+1.9 +7.6	+ 2.9 + 9.5	+ 5.7 +13.3	+ 9.5 +19.0	+15.2 +26.6	+22.8 +41.8
20	17.1–18.99	−8.0 −2.0	−6.0 0	−4.0 +2.0	−3.0 +3.0	−2.0 +4.0	−1.0 +5.0	0 +6.0	+1.0 +7.0	+2.0 +8.0	+ 3.0 +10.0	+ 6.0 +14.0	+10.0 +20.0	+16.0 +28.0	+24.0 +44.0
21	19.0–20.99	−8.4 −2.1	−6.3 0	−4.2 +2.1	−3.1 +3.2	−2.1 +4.2	−1.0 +5.3	0 +6.3	+1.1 +7.4	+2.1 +8.4	+ 3.2 +10.5	+ 6.3 +14.7	+10.5 +21.0	+16.8 +29.4	+25.2 +46.2
22	21.0–23.09	−8.8 −2.2	−6.6 0	−4.4 +2.2	−3.3 +3.3	−2.2 +4.4	−1.1 +5.5	0 +6.6	+1.1 +7.7	+2.2 +8.8	+ 3.3 +11.0	+ 6.6 +15.4	+11.0 +22.0	+17.6 +30.8	+26.4 +48.4
23	23.1–25.29	−9.2 −2.3	−6.9 0	−4.6 +2.3	−3.4 +3.5	−2.3 +4.6	−1.1 +5.8	0 +6.9	+1.2 +8.1	+2.3 +9.2	+ 3.5 +11.5	+ 6.9 +16.1	+11.5 +23.0	+18.4 +32.2	+27.6 +50.6

+ = Clearance. − = Interference.
The upper figures in each square represent the minimum, the lower figures the maximum, limit of fit.

TABLE 3.—*Continued*

1	2	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Size Multiplier	Nominal Sizes	STANDARD SHAFTS IN BILATERAL "X" HOLES													
m	Inches	XF	XE	XD	XC	XB	XK	XL	XP	XM	XQ	XR	XS	XT	XTT
3	0– 0.29	− 1.5	−1.2	−0.9	−0.7	−0.6	−0.4	−0.3	−0.1	0	+0.2	+ 0.6	+ 1.2	+ 2.1	+ 3.3
		− 0.6	−0.3	0	+0.2	+0.3	+0.5	+0.6	+0.8	+0.9	+1.2	+ 1.8	+ 2.7	+ 3.9	+ 6.3
4	0.3– 0.59	− 2.0	−1.6	−1.2	−1.0	−0.8	−0.6	−0.4	−0.2	0	+0.2	+ 0.8	+ 1.6	+ 2.8	+ 4.4
		− 0.8	−0.4	0	+0.2	+0.4	+0.6	+0.8	+1.0	+1.2	+1.6	+ 2.4	+ 3.6	+ 5.2	+ 8.4
5	0.6– 0.99	− 2.5	−2.0	−1.5	−1.2	−1.0	−0.7	−0.5	−0.2	0	+0.3	+ 1.0	+ 2.0	+ 3.5	+ 5.5
		− 1.0	−0.5	0	+0.3	+0.5	+0.8	+1.0	+1.3	+1.5	+2.0	+ 3.0	+ 4.5	+ 6.5	+10.5
6	1.0– 1.49	− 3.0	−2.4	−1.8	−1.5	−1.2	−0.9	−0.6	−0.3	0	+0.3	+ 1.2	+ 2.4	+ 4.2	+ 6.6
		− 1.2	−0.6	0	+0.3	+0.6	+0.9	+1.2	+1.5	+1.8	+2.4	+ 3.6	+ 5.4	+ 7.8	+12.6
7	1.5– 2.09	− 3.5	−2.8	−2.1	−1.7	−1.4	−1.0	−0.7	−0.3	0	+0.4	+ 1.4	+ 2.8	+ 4.9	+ 7.7
		− 1.4	−0.7	0	+0.4	+0.7	+1.1	+1.4	+1.8	+2.1	+2.8	+ 4.2	+ 6.3	+ 9.1	+14.7
8	2.1– 2.79	− 4.0	−3.2	−2.4	−2.0	−1.6	−1.2	−0.8	−0.4	0	+0.4	+ 1.6	+ 3.2	+ 5.6	+ 8.8
		− 1.6	−0.8	0	+0.4	+0.8	+1.2	+1.6	+2.0	+2.4	+3.2	+ 4.8	+ 7.2	+10.4	+16.8
9	2.8– 3.59	− 4.5	−3.6	−2.7	−2.2	−1.8	−1.3	−0.9	−0.4	0	+0.5	+ 1.8	+ 3.6	+ 6.3	+ 9.9
		− 1.8	−0.9	0	+0.5	+0.9	+1.4	+1.8	+2.3	+2.7	+3.6	+ 5.4	+ 8.1	+11.7	+18.9
10	3.6– 4.49	− 5.0	−4.0	−3.0	−2.5	−2.0	−1.5	−1.0	−0.5	0	+0.5	+ 2.0	+ 4.0	+ 7.0	+11.0
		− 2.0	−1.0	0	+0.5	+1.0	+1.5	+2.0	+2.5	+3.0	+4.0	+ 6.0	+ 9.0	+13.0	+21.0
11	4.5– 5.49	− 5.5	−4.4	−3.3	−2.7	−2.2	−1.6	−1.1	−0.5	0	+0.6	+ 2.2	+ 4.4	+ 7.7	+12.1
		− 2.2	−1.1	0	+0.6	+1.1	+1.7	+2.2	+2.8	+3.3	+4.4	+ 6.6	+ 9.9	+14.3	+23.1
12	5.5– 6.59	− 6.0	−4.8	−3.6	−3.0	−2.4	−1.8	−1.2	−0.6	0	+0.6	+ 2.4	+ 4.8	+ 8.4	+13.2
		− 2.4	−1.2	0	+0.6	+1.2	+1.8	+2.4	+3.0	+3.6	+4.8	+ 7.2	+10.8	+15.6	+25.2
13	6.6– 7.79	− 6.5	−5.2	−3.9	−3.2	−2.6	−1.9	−1.3	−0.6	0	+0.7	+ 2.6	+ 5.2	+ 9.1	+14.3
		− 2.6	−1.3	0	+0.7	+1.3	+2.0	+2.6	+3.3	+3.9	+5.2	+ 7.8	+11.7	+16.9	+27.3
14	7.8– 9.09	− 7.0	−5.6	−4.2	−3.5	−2.8	−2.1	−1.4	−0.7	0	+0.7	+ 2.8	+ 5.6	+ 9 8	+15.4
		− 2.8	−1.4	0	+0.7	+1.4	+2.1	+2.8	+3.5	+4.2	+5.6	+ 8.4	+12.6	+18.2	+29.4

TABLE—3. *Continued*

1	2	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Size Multiplier	Nominal Sizes	STANDARD SHAFTS IN BILATERAL "X" HOLES													
m	Inches	XF	XE	XD	XC	XB	XK	XL	XP	XM	XQ	XR	XS	XT	XTT
15	9.1–10.49	− 7.5	−6.0	−4.5	−3.7	−3.0	−2.2	−1.5	−0.7	0	+0.8	+ 3.0	+ 6.0	+10.5	+16.5
		− 3.0	−1.5	0	+0.8	+1.5	+2.3	+3.0	+3.8	+4.5	+6.0	+ 9.0	+13.5	+19.5	+31.5
16	10.5–11.99	− 8.0	−6.4	−4.8	−4.0	−3.2	−2.4	−1.6	−0.8	0	+0.8	+ 3.2	+ 6.4	+11.2	+17.6
		− 3.2	−1.6	0	+0.8	+1.6	+2.4	+3.2	+4.0	+4.8	+6.4	+ 9.6	+14.4	+20.8	+33.6
17	12.0–13.59	− 8.5	−6.8	−5.1	−4.2	−3.4	−2.5	−1.7	−0.8	0	+0.9	+ 3.4	+ 6.8	+11.9	+18.7
		− 3.4	−1.7	0	+0.9	+1.7	+2.6	+3.4	+4.3	+5.1	+6.8	+ 10.2	+15.3	+22.1	+35.7
18	13.6–15.29	− 9.0	−7.2	−5.4	−4.5	−3.6	−2.7	−1.8	−0.9	0	+0.9	+ 3.6	+ 7.2	+12.6	+19.8
		− 3.6	−1.8	0	+0.9	+1.8	+2.7	+3.6	+4.5	+5.4	+7.2	+10.8	+16.2	+23.4	+37.8
19	15.3–17.09	− 9.5	−7.6	−5.7	−4.7	−3.8	−2.8	−1.9	−0.9	0	+1.0	+ 3.8	+ 7.6	+13.3	+20.9
		− 3.8	−1.9	0	+1.0	+1.9	+2.9	+3.8	+4.8	+5.7	+7.6	+11.4	+17.1	+24.7	+39.9
20	17.1–18.99	−10.0	−8.0	−6.0	−5.0	−4.0	−3.0	−2.0	−1.0	0	+1.0	+ 4.0	+ 8.0	+14.0	+22.0
		− 4.0	−2.0	0	+1.0	+2.0	+3.0	+4.0	+5.0	+6.0	+8.0	+12.0	+18.0	+26.0	+42.0
21	19.0–20.99	−10.5	−8.4	−6.3	−5.2	−4.2	−3.1	−2.1	−1.0	0	+1.1	+ 4.2	+ 8.4	+14.7	+23.1
		− 4.2	−2.1	0	+1.1	+2.1	+3.2	+4.2	+5.3	+6.3	+8.4	+12.6	+18.9	+27.3	+44.1
22	21.0–23.09	−11.0	−8.8	−6.6	−5.5	−4.4	−3.3	−2.2	−1.1	0	+1.1	+ 4.4	+ 8.8	+15.4	+24.2
		− 4.4	−2.2	0	+1.1	+2.2	+3.3	+4.4	+5.5	+6.6	+8.8	+13.2	+19.8	+28.6	+46.2
23	23.1–25.29	−11.5	−9.2	−6.9	−5.7	−4.6	−3.4	−2.3	−1.1	0	+1.2	+ 4.6	+ 9.2	+16.1	+25.3
		− 4.6	−2.3	0	+1.2	+2.3	+3.5	+4.6	+5.8	+6.9	+9.2	+13.8	+20.7	+29.9	+48.3

\+ = Clearance.
− = Interference.
The upper figures in each square represent the minimum, the lower figures the maximum, limit of fit.

WOODRUFF KEYS

The diagrams and tables show the Woodruff type of Key as standardized by the Whitney Mfg. Co. Fig. 1 shows Keys from $\frac{1}{4}$ to $1\frac{1}{2}$ inch in diameter, and Fig. 2, from $2\frac{1}{8}$ to $3\frac{1}{2}$ inches. A few sizes below $1\frac{1}{2}$ inches have the ends cut off, as in Fig. 2. These tables give tolerances for each dimension and also, at *E*, the distance from bottom of Keyway to top of Key, this being useful in determining the depth of cut to be taken. The last two columns give the width of Keyseat to provide a tight fit and the width of Keyway to insure the Key entering the hub.

These Keys fit Keyseats made by corresponding cutters without filing or fitting.

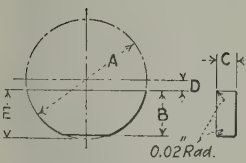


FIG. 1

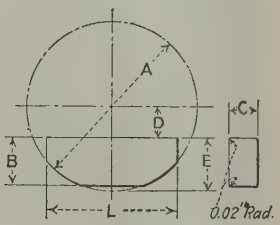


FIG. 2

DEPTH OF WOODRUFF KEYWAYS IN SHAFT
(Contributed by A. W. WILKS)

No.	Inches	No.	Inches	No.	Inches	No.	Inches
1	.1719	12	.2657	20	.4376	27	.4063
2	.1564	A	.250	21	.4219	28	.3751
3	.1407	13	.3438	D	.3907	29	.3438
4	.2032	14	.3282	E	.3594	R	.625
5	.1875	15	.3125	22	.4688	S	.5938
6	.1719	B	.2813	23	.4376	T	.5625
7	.250	16	.3907	F	.4063	U	.5313
8	.2344	17	.3751	24	.5157	V	.500
9	.2188	18	.3594	25	.4845	30	.750
10	.2969	C	.3282	G	.4532	31	.7188
11	.2813	19	.4532	26	.4376	32	.6875

Whitney Standard for Woodruff Keys

Key No.	Diam. of Key *A*	Height of Key *B*	Thickness of Key *C*	Key Cut Below Center *D*	*E*	Width of Key-seat	Width of Key-way
0	0.250 0.260	0.112 0.117	0.0625 0.0635	0.008	0.112 0.117	0.0615 0.0625	0.0635 0.0645
00	0.3215 0.3225	0.135 0.140	0.0937 0.0947	$\frac{1}{64}$ + 0.005	0.135 0.140	0.0927 0.0937	0.0947 0.0957
000	0.375 0.385	0.167 0.172	0.125 0.126	$\frac{1}{64}$ + 0.005	0.167 0.172	0.124 0.125	0.126 0.127
1	0.500 0.510	0.187 0.193	0.0625 0.0635	$\frac{3}{64}$ + 0.005	0.198 0.203	0.0615 0.0625	0.0635 0.0645
2	0.500 0.510	0.187 0.193	0.0937 0.0947	$\frac{3}{64}$ + 0.005	0.198 0.203	0.0927 0.0937	0.0947 0.0957
3	0.500 0.510	0.187 0.193	0.125 0.126	$\frac{3}{64}$ + 0.005	0.198 0.203	0.124 0.125	0.126 0.127
4	0.625 0.635	0.234 0.240	0.0937 0.0947	$\frac{1}{16}$ + 0.005	0.245 0.250	0.0927 0.0937	0.0947 0.0957
5	0.625 0.635	0.234 0.240	0.125 0.126	$\frac{1}{16}$ + 0.005	0.245 0.250	0.124 0.125	0.126 0.127
6	0.625 0.635	0.234 0.240	0.1562 0.1572	$\frac{1}{16}$ + 0.005	0.245 0.250	0.1552 0.1562	0.1572 0.1582
61	0.625 0.635	0.234 0.240	0.1875 0.1885	$\frac{1}{16}$ + 0.005	0.245 0.250	0.1865 0.1875	0.1885 0.1895
7	0.750 0.760	0.296 0.302	0.125 0.126	$\frac{1}{16}$ + 0.005	0.308 0.313	0.124 0.125	0.126 0.127
8	0.750 0.760	0.296 0.302	0.1562 0.1572	$\frac{1}{16}$ + 0.005	0.308 0.313	0.1552 0.1562	0.1572 0.1582
9	0.750 0.760	0.296 0.302	0.1875 0.1885	$\frac{1}{16}$ + 0.005	0.308 0.313	0.1865 0.1875	0.1885 0.1895
01	0.750 0.760	0.296 0.302	0.250 0.251	$\frac{1}{16}$ + 0.005	0.308 0.313	0.249 0.250	0.251 0.252
10	0.875 0.885	0.359 0.365	0.1562 0.1572	$\frac{1}{16}$ + 0.005	0.370 0.375	0.1552 0.1562	0.1572 0.1582
11	0.875 0.885	0.359 0.365	0.1875 0.1885	$\frac{1}{16}$ + 0.005	0.370 0.375	0.1865 0.1875	0.1885 0.1895
12	0.875 0.885	0.359 0.365	0.2187 0.2197	$\frac{1}{16}$ + 0.005	0.370 0.375	0.2177 0.2187	0.2197 0.2207
A	0.875 0.885	0.359 0.365	0.250 0.251	$\frac{1}{16}$ + 0.005	0.370 0.375	0.249 0.250	0.251 0.252
121	0.875 0.885	0.292 0.295	0.250 0.251	$\frac{1}{16}$ + 0.005	0.370 0.375	0.249 0.250	0.251 0.252
13	1.000 1.010	0.421 0.427	0.1875 0.1885	$\frac{1}{16}$ + 0.005	0.433 0.438	0.1865 0.1875	0.1885 0.1895
14	1.000 1.010	0.421 0.427	0.2187 0.2197	$\frac{1}{16}$ + 0.005	0.433 0.438	0.2177 0.2187	0.2197 0.2207

WHITNEY STANDARD FOR WOODRUFF KEYS.—*Continued*

Key No.	Diam. of Key *A*	Height of Key *B*	Thickness of Key *C*	Key Cut Below Center *D*	*E*	Width of Key-seat	Width of Key-way
15	1.000 1.010	0.421 0.427	0.250 0.251	$\frac{1}{16}$ + 0.005	0.433 0.438	0.249 0.250	0.251 0.252
B	1.000 1.010	0.421 0.427	0.3125 0.3135	$\frac{1}{16}$ + 0.005	0.433 0.438	0.3115 0.3125	0.3135 0.3145
152	1.000 1.010	0.421 0.427	0.375 0.376	$\frac{1}{16}$ + 0.005	0.433 0.438	0.374 0.375	0.376 0.377
141	1.000 1.010	0.359 0.365	0.250 0.251	$\frac{1}{8}$ + 0.005	0.370 0.375	0.249 0.250	0.251 0.252
131	1.000 1.010	0.344 0.350	0.3125 0.3135	$\frac{1}{16}$ + 0.005	0.433 0.438	0.3115 0.3125	0.3135 0.3145
16	1.125 1.135	0.468 0.474	0.1875 0.1885	$\frac{5}{64}$ + 0.005	0.480 0.485	0.1865 0.1875	0.1885 0.1895
17	1.125 1.135	0.468 0.474	0.2187 0.2197	$\frac{5}{64}$ + 0.005	0.480 0.485	0.2177 0.2187	0.2197 0.2207
18	1.125 1.135	0.468 0.474	0.250 0.251	$\frac{5}{64}$ + 0.005	0.480 0.485	0.249 0.250	0.251 0.252
C	1.125 1.135	0.468 0.474	0.3125 0.3135	$\frac{5}{64}$ + 0.005	0.480 0.485	0.3115 0.3125	0.3135 0.3145
161	1.125 1.135	0.468 0.474	0.3125 0.3135	$\frac{5}{64}$ + 0.005	0.480 0.485	0.3115 0.3125	0.3135 0.3145
19	1.250 1.260	0.531 0.537	0.1875 0.1885	$\frac{5}{64}$ + 0.005	0.542 0.547	0.1865 0.1875	0.1885 0.1895
20	1.250 1.260	0.531 0.537	0.2187 0.2197	$\frac{5}{64}$ + 0.005	0.542 0.547	0.2177 0.2187	0.2197 0.2207
21	1.250 1.260	0.531 0.537	0.250 0.251	$\frac{5}{64}$ + 0.005	0.542 0.547	0.249 0.250	0.251 0.252
D	1.250 1.260	0.531 0.537	0.3125 0.3135	$\frac{5}{64}$ + 0.005	0.542 0.547	0.3115 0.3125	0.3135 0.3145
E	1.250 1.260	0.531 0.537	0.375 0.376	$\frac{5}{64}$ + 0.005	0.542 0.547	0.374 0.375	0.376 0.377
22	1.375 1.385	0.578 0.584	0.250 0.251	$\frac{3}{32}$ + 0.005	0.589 0.594	0.249 0.250	0.251 0.252
23	1.375 1.385	0.578 0.584	0.3125 0.3135	$\frac{3}{32}$ + 0.005	0.589 0.594	0.3115 0.3125	0.3135 0.3145
F	1.375 1.385	0.578 0.384	0.375 0.376	$\frac{3}{32}$ + 0.005	0.589 0.594	0.374 0.375	0.376 0.377
24	1.500 1.510	0.625 0.631	0.250 0.251	$\frac{7}{64}$ + 0.005	0.635 0.640	0.249 0.250	0.251 0.252
25	1.500 1.510	0.625 0.631	0.3125 0.3135	$\frac{7}{64}$ + 0.005	0.635 0.640	0.3115 0.3125	0.3135 0.3145
G	1.500 1.510	0.625 0.631	0.375 0.376	$\frac{7}{64}$ + 0.005	0.635 0.640	0.374 0.375	0.376 0.377

WHITNEY STANDARD FOR WOODRUFF KEYS.—*Continued*

Key No.	Diam. of Key *A*	Height of Key *B*	Thickness of Key *C*	Length of Key *L*	Key Cut Below Center *D*	*E*	Width of Keyseat	Width of Keyway
126	2.125	0.390	0.1875	1.370	$\frac{21}{32}$ + 0.005	0.401	0.1865	0.1885
	2.135	0.396	0.1885	1.380		0.406	0.1875	0.1895
127	2.125	0.390	0.250	1.370	$\frac{21}{32}$ + 0.005	0.401	0.249	0.251
	2.135	0.396	0.251	1.380		0.406	0.350	0.252
128	2.125	0.390	0.3125	1.370	$\frac{21}{32}$ + 0.005	0.401	0.3115	0.3135
	2.135	0.396	0.3135	1.380		0.406	0.3125	0.3145
129	2.125	0.390	0.375	1.370	$\frac{21}{32}$ + 0.005	0.401	0.374	0.376
	2.135	0.396	0.376	1.380		0.406	0.375	0.377
26	2.125	0.515	0.1875	1.713	$\frac{17}{32}$ + 0.005	0.526	0.1865	0.1885
	2.135	0.521	0.1885	1.723		0.531	0.1875	0.1895
27	2.125	0.515	0.250	1.713	$\frac{17}{32}$ + 0.005	0.526	0.249	0.251
	2.135	0.521	0.251	1.723		0.531	0.250	0.252
28	2.125	0.515	0.3125	1.713	$\frac{17}{32}$ + 0.005	0.526	0.3115	0.3135
	2.135	0.521	0.3135	1.723		0.531	0.3125	0.3145
29	2.125	0.515	0.375	1.713	$\frac{17}{32}$ + 0.005	0.526	0.374	0.376
	2.135	0.521	0.376	1.723		0.531	0.375	0.377
Rx	2.750	0.578	0.250	1.995	$\frac{25}{32}$ + 0.005	0.589	0.249	0.251
	2.760	0.584	0.251	2.005		0.594	0.250	0.252
Sx	2.750	0.578	0.3125	1.995	$\frac{25}{32}$ + 0.005	0.589	0.3115	0.3135
	2.760	0.584	0.3135	2.005		0.594	0.3125	0.3145
Tx	2.750	0.578	0.375	1.995	$\frac{25}{32}$ + 0.005	0.589	0.374	0.376
	2.760	0.584	0.376	2.005		0.594	0.375	0.377
Ux	2.750	0.578	0.4375	1.995	$\frac{25}{32}$ + 0.005	0.589	0.4365	0.4385
	2.760	0.584	0.4385	2.005		0.594	0.4375	0.4395
Vx	2.750	0.578	0.500	1.995	$\frac{25}{32}$ + 0.005	0.589	0.499	0.501
	2.760	0.584	0.501	2.005		0.594	0.500	0.502
R	2.750	0.734	0.250	2.307	$\frac{3}{8}$ + 0.005	0.745	0.249	0.251
	2.760	0.740	0.251	2.317		0.750	0.250	0.252
S	2.750	0.734	0.3125	2.307	$\frac{3}{8}$ + 0.005	0.745	0.3115	0.3135
	2.760	0.740	0.3135	2.317		0.750	0.3125	0.3145
T	2.750	0.734	0.375	2.307	$\frac{3}{8}$ + 0.005	0.745	0.374	0.376
	2.760	0.740	0.376	2.317		0.750	0.375	0.377
U	2.750	0.734	0.4375	2.307	$\frac{3}{8}$ + 0.005	0.745	0.4365	0.4385
	2.760	0.740	0.4385	2.317		0.750	0.4375	0.4395
V	2.750	0.734	0.500	2.307	$\frac{3}{8}$ + 0.005	0.745	0.499	0.501
	2.760	0.740	0.501	2.317		0.750	0.500	0.502
30	3.500	0.921	0.375	2.870	$\frac{13}{16}$ + 0.005	0.933	0.374	0.376
	3.510	0.927	0.376	2.880		0.938	0.375	0.377
31	3.500	0.921	0.4375	2.870	$\frac{13}{16}$ + 0.005	0.933	0.4365	0.4385
	3.510	0.927	0.4385	2.880		0.938	0.4375	0.4395
32	3.500	0.921	0.500	2.870	$\frac{13}{16}$ + 0.005	0.933	0.499	0.501
	3.510	0.927	0.501	2.880		0.938	0.500	0.502
33	3.500	0.921	0.5625	2.870	$\frac{13}{16}$ + 0.005	0.933	0.5615	0.5635
	3.510	0.927	0.5635	2.880		0.938	0.5625	0.5645
34	3.500	0.921	0.625	2.870	$\frac{13}{16}$ + 0.005	0.933	0.624	0.626
	3.510	0.927	0.626	2.880		0.938	0.625	0.627
35	3.500	0.921	0.6875	2.870	$\frac{13}{16}$ + 0.005	0.933	0.6865	0.6885
	3.510	0.927	0.6885	2.880		0.938	0.6875	0.6895
36	3.500	0.921	0.750	2.870	$\frac{13}{16}$ + 0.005	0.933	0.749	0.751
	3.510	0.927	0.751	2.880		0.938	0.750	0.752

DIMENSIONS OF KEYS AND KEY-SEATS

THE following rules and table on page 558, as prepared by Baker Bros., Toledo, Ohio, give dimension of keys and key-seats.

The width of the key should equal one-fourth the diameter of the shaft.

The thickness of the key should equal one-sixth the diameter of the shaft.

The depth in the hub for a straight key-seat should be one-half the thickness of the key.

The depth in the hub at the large end, for a taper key-seat, should be three-fifths the thickness of the key.

The taper for all key-seats should be $\frac{3}{16}$ inch in 1 foot of length.

The depth to be cut in the hub for taper key-seats, at the large end, is greater than those cut straight, for the reason that unless this is done the depth in the hub at the small end will not be sufficient, especially in long key-seats.

The depths of key-seats in the table are given in thousandths of an inch and measured from the edge of the key-seat, and not from the center. In this manner the exact depth of key-seat can be measured at any time after it is cut.

For extra long key-seats the depth cut in the hub may be slightly increased but for the average work the table will be found correct.

Dimensions of Keys and Key-Seats. (Baker Bros.)

Size of Hole	Decimal Equivalent	Preferred Width of Key-Seat	Nearest Size of Cutter	Preferred Thickness of Key	Nearest Fractional Thickness	Depth to be Cut in Hub for Straight Key	Depth at Large End for Taper Key
1	1.	.25	1/4	.166	5/32	.093	.112
1 1/16	1.062	.265	1/4	.177	5/32	.093	.112
1 1/8	1.125	.281	1/4	.187	3/16	.093	.112
1 3/16	1.187	.296	5/16	.198	7/32	.109	.131
1 1/4	1.25	.312	5/16	.208	7/32	.109	.131
1 5/16	1.312	.328	5/16	.219	7/32	.109	.131
1 3/8	1.375	.343	3/8	.229	1/4	.125	.15
1 7/16	1.437	.359	3/8	.239	1/4	.125	.15
1 1/2	1.5	.375	3/8	.25	1/4	.125	.15
1 9/16	1.562	.39	3/8	.26	1/4	.125	.15
1 5/8	1.625	.406	7/16	.271	9/32	.141	.168
1 11/16	1.687	.421	7/16	.281	9/32	.141	.168
1 3/4	1.75	.437	7/16	.292	9/32	.141	.168
1 13/16	1.812	.453	7/16	.302	9/32	.141	.168
1 7/8	1.875	.468	1/2	.312	11/32	.171	.206
1 15/16	1.937	.484	1/2	.323	11/32	.171	.206
2	2.	.5	1/2	.333	11/32	.171	.206
2 1/16	2.062	.515	1/2	.344	11/32	.171	.206
2 1/8	2.125	.531	1/2	.354	11/32	.171	.206
2 3/16	2.187	.547	1/2	.364	11/32	.171	.206
2 1/4	2.25	.563	1/2	.375	11/32	.171	.206
2 5/16	2.312	.578	1/2	.385	11/32	.171	.206
2 3/8	2.375	.593	5/8	.396	7/16	.218	.262
2 7/16	2.437	.609	5/8	.406	7/16	.218	.262
2 1/2	2.5	.625	5/8	.416	7/16	.218	.262
2 9/16	2.562	.641	5/8	.427	7/16	.218	.262
2 5/8	2.625	.656	5/8	.437	7/16	.218	.262
2 11/16	2.687	.672	5/8	.448	7/16	.218	.262
2 3/4	2.75	.687	5/8	.458	7/16	.218	.262
2 13/16	2.812	.703	5/8	.469	7/16	.218	.262
2 7/8	2.875	.719	3/4	.479	1/2	.25	.3
2 15/16	2.937	.734	3/4	.49	1/2	.25	.3
3	3.	.75	3/4	.5	1/2	.25	.3
3 1/8	3.125	.781	3/4	.521	1/2	.25	.3
3 3/16	3.187	.797	3/4	.531	1/2	.25	.3
3 1/4	3.25	.812	3/4	.542	1/2	.25	.3
3 3/8	3.375	.844	7/8	.562	5/8	.312	.375
3 7/16	3.437	.859	7/8	.573	5/8	.312	.375
3 1/2	3.5	.875	7/8	.583	5/8	.312	.375
3 5/8	3.625	.906	7/8	.604	5/8	.312	.375
3 11/16	3.687	.923	7/8	.614	5/8	.312	.375
3 3/4	3.75	.937	7/8	.625	5/8	.312	.375
3 7/8	3.875	.969	1	.646	11/16	.343	.412
3 15/16	3.937	.984	1	.656	11/16	.343	.412
4	4.	1.	1	.666	11/16	.343	.412

Cold-finished Shafting Standard Diameters and Lengths

Approved as Tentative American Standard, December, 1924.

Diameters and Tolerances

Transmission Shafting Sizes in Inches	Machinery Shafting Sizes in Inches	Tolerances[1] on Diameters (−) in Inches	Transmission Shafting Sizes in Inches	Machinery Shafting Sizes in Inches	Tolerances[1] on Diameters (−) in Inches
	$\frac{1}{2}$	0.002	$2\frac{3}{16}$	$2\frac{3}{16}$	0.004
	$\frac{9}{16}$	0.002		$2\frac{1}{4}$	0.004
	$\frac{5}{8}$	0.002		$2\frac{5}{16}$	0.004
	$\frac{11}{16}$	0.002		$2\frac{3}{8}$	0.004
	$\frac{3}{4}$	0.002	$2\frac{7}{16}$	$2\frac{7}{16}$	0.004
	$\frac{13}{16}$	0.002		$2\frac{1}{2}$	0.004
	$\frac{7}{8}$	0.002		$2\frac{5}{8}$	0.004
$1\frac{15}{16}$	$1\frac{15}{16}$	0.002		$2\frac{3}{4}$	0.004
	1	0.002		$2\frac{7}{8}$	0.004
	$1\frac{1}{16}$	0.003	$2\frac{15}{16}$	3	0.004
	$1\frac{1}{8}$	0.003		$3\frac{1}{8}$	0.004
$1\frac{3}{16}$	$1\frac{3}{16}$	0.003		$3\frac{1}{4}$	0.004
	$1\frac{1}{4}$	0.003		$3\frac{3}{8}$	0.004
	$1\frac{5}{16}$	0.003	$3\frac{7}{16}$	$3\frac{1}{2}$	0.004
	$1\frac{3}{8}$	0.003		$3\frac{5}{8}$	0.004
$1\frac{7}{16}$	$1\frac{7}{16}$	0.003		$3\frac{3}{4}$	0.004
	$1\frac{1}{2}$	0.003		$3\frac{7}{8}$	0.004
	$1\frac{9}{16}$	0.003	$3\frac{15}{16}$	4	0.004
	$1\frac{5}{8}$	0.003		$4\frac{1}{4}$	0.005
$1\frac{11}{16}$	$1\frac{11}{16}$	0.003	$4\frac{7}{16}$	$4\frac{1}{2}$	0.005
	$1\frac{3}{4}$	0.003		$4\frac{3}{4}$	0.005
	$1\frac{13}{16}$	0.003	$4\frac{15}{16}$	5	0.005
	$1\frac{7}{8}$	0.003		$5\frac{1}{4}$	0.005
$1\frac{15}{16}$	$1\frac{15}{16}$	0.003	$5\frac{7}{16}$	$5\frac{1}{2}$	0.005
	2	0.003		$5\frac{3}{4}$	0.005
	$2\frac{1}{16}$	0.004	$5\frac{15}{16}$	6	0.005
	$2\frac{1}{8}$	0.004			

[1] Note.—These tolerances are *negative* and represent the maximum allowable variation *below* the exact nominal size. For instance, the maximum diameter of the $1\frac{15}{16}$-inch shaft is 1.938 inch and its minimum allowable diameter is 1.935 inch.

Standard stock lengths for cold-finished shafting shall be 16, 20 and 24 feet.

Square and Flat Stock Keys Standard Widths and Heights

Approved as Tentative American Standard, June 1925

Dimensions and Tolerances

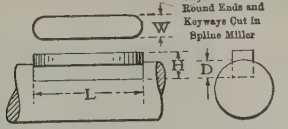
Shaft Diameters d in Inches	Square Stock Keys w in Inches	Flat Stock Keys $w \times h$ in Inches	Tolerances[1] on Stock Keys (−) in Inches	Shaft Diameters d in Inches	Square Stock Keys w in Inches	Flat Stock Keys $w \times h$ in Inches	Tolerances[1] on Stock Keys (−) in Inches
$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8} \times \frac{3}{32}$	0.0020	$2\frac{3}{8}$	$\frac{5}{8}$	$\frac{5}{8} \times \frac{7}{16}$	0.0025
$\frac{9}{16}$	$\frac{1}{8}$	$\frac{1}{8} \times \frac{3}{32}$	0.0020	$2\frac{7}{16}$	$\frac{5}{8}$	$\frac{5}{8} \times \frac{7}{16}$	0.0025
$\frac{5}{8}$	$\frac{3}{16}$	$\frac{3}{16} \times \frac{1}{8}$	0.0020	$2\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8} \times \frac{7}{16}$	0.0025
$\frac{11}{16}$	$\frac{3}{16}$	$\frac{3}{16} \times \frac{1}{8}$	0.0020	$2\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8} \times \frac{7}{16}$	0.0025
$\frac{3}{4}$	$\frac{3}{16}$	$\frac{3}{16} \times \frac{1}{8}$	0.0020	$2\frac{3}{4}$	$\frac{5}{8}$	$\frac{5}{8} \times \frac{7}{16}$	0.0025
$\frac{13}{16}$	$\frac{3}{16}$	$\frac{3}{16} \times \frac{1}{8}$	0.0020	$2\frac{7}{8}$	$\frac{3}{4}$	$\frac{3}{4} \times \frac{1}{2}$	0.0025
$\frac{7}{8}$	$\frac{3}{16}$	$\frac{3}{16} \times \frac{1}{8}$	0.0020	$2\frac{15}{16}$	$\frac{3}{4}$	$\frac{3}{4} \times \frac{1}{2}$	0.0025
$\frac{15}{16}$	$\frac{1}{4}$	$\frac{1}{4} \times \frac{3}{16}$	0.0020	3	$\frac{3}{4}$	$\frac{3}{4} \times \frac{1}{2}$	0.0025
1	$\frac{1}{4}$	$\frac{1}{4} \times \frac{3}{16}$	0.0020	$3\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4} \times \frac{1}{2}$	0.0025
$1\frac{1}{16}$	$\frac{1}{4}$	$\frac{1}{4} \times \frac{3}{16}$	0.0020	$3\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4} \times \frac{1}{2}$	0.0025
$1\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4} \times \frac{3}{16}$	0.0020	$3\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8} \times \frac{5}{8}$	0.0030
$1\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4} \times \frac{3}{16}$	0 0020	$3\frac{7}{16}$	$\frac{7}{8}$	$\frac{7}{8} \times \frac{5}{8}$	0.0030
$1\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4} \times \frac{3}{16}$	0.0020	$3\frac{1}{2}$	$\frac{7}{8}$	$\frac{7}{8} \times \frac{5}{8}$	0.0030
$1\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16} \times \frac{1}{4}$	0.0020	$3\frac{9}{16}$	$\frac{7}{8}$	$\frac{7}{8} \times \frac{5}{8}$	0.0030
$1\frac{3}{8}$	$\frac{5}{16}$	$\frac{5}{16} \times \frac{1}{4}$	0.0020	$3\frac{5}{8}$	$\frac{7}{8}$	$\frac{7}{8} \times \frac{5}{8}$	0.0030
$1\frac{7}{16}$	$\frac{3}{8}$	$\frac{3}{8} \times \frac{1}{4}$	0.0020	$3\frac{11}{16}$	1	$1 \times \frac{3}{4}$	0.0030
$1\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8} \times \frac{1}{4}$	0.0020	$3\frac{15}{16}$	1	$1 \times \frac{3}{4}$	0.0030
$1\frac{9}{16}$	$\frac{3}{8}$	$\frac{3}{8} \times \frac{1}{4}$	0.0020	4	1	$1 \times \frac{3}{4}$	0.0030
$1\frac{5}{8}$	$\frac{3}{8}$	$\frac{3}{8} \times \frac{1}{4}$	0.0020	$4\frac{1}{16}$	1	$1 \times \frac{3}{4}$	0.0030
$1\frac{11}{16}$	$\frac{3}{8}$	$\frac{3}{8} \times \frac{1}{4}$	0.0020	$4\frac{1}{16}$	1	$1 \times \frac{3}{4}$	0.0030
$1\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8} \times \frac{1}{4}$	0.0020	$4\frac{1}{8}$	1	$1 \times \frac{3}{4}$	0.0030
$1\frac{13}{16}$	$\frac{1}{2}$	$\frac{1}{2} \times \frac{3}{8}$	0.0025	$4\frac{3}{16}$	$1\frac{1}{4}$	$1\frac{1}{4} \times \frac{7}{8}$	0.0030
$1\frac{7}{8}$	$\frac{1}{2}$	$\frac{1}{2} \times \frac{3}{8}$	0.0025	$4\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4} \times \frac{7}{8}$	0.0030
$1\frac{15}{16}$	$\frac{1}{2}$	$\frac{1}{2} \times \frac{3}{8}$	0.0025	$4\frac{5}{16}$	$1\frac{1}{4}$	$1\frac{1}{4} \times \frac{7}{8}$	0.0030
2	$\frac{1}{2}$	$\frac{1}{2} \times \frac{3}{8}$	0.0025	$5\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4} \times \frac{7}{8}$	0.0030
$2\frac{1}{16}$	$\frac{1}{2}$	$\frac{1}{2} \times \frac{3}{8}$	0.0025	$5\frac{7}{16}$	$1\frac{1}{4}$	$1\frac{1}{4} \times \frac{7}{8}$	0.0030
$2\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{2} \times \frac{3}{8}$	0.0025	$5\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2} \times \frac{7}{8}$	0.0030
$2\frac{3}{16}$	$\frac{1}{2}$	$\frac{1}{2} \times \frac{3}{8}$	0.0025	$5\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2} \times 1$	0.0030
$2\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2} \times \frac{3}{8}$	0.0025	$5\frac{15}{16}$	$1\frac{1}{2}$	$1\frac{1}{2} \times 1$	0.0030
$2\frac{5}{16}$	$\frac{5}{8}$	$\frac{5}{8} \times \frac{7}{16}$	0.0025	6	$1\frac{1}{2}$	$1\frac{1}{2} \times 1$	0.0030

[1] Note.—These tolerances are *negative* and represent the maximum allowable variation *below* the exact nominal size. For instance, the standard stock square key for a 2-inch shaft has a maximum size of 0.500 × 0.500 inch and a minimum size of 0.4975 × 0.4975 inch.

It is understood that these keys are to be cut from cold-finished stock and are to be used without machining.

Pratt & Whitney, Round End Keys

The length "L" may vary from the table given, but must at least be equal to (2 × W). The maximum length of slot is (4" + W). Note that the width (W) is in all cases equal to the depth (D).



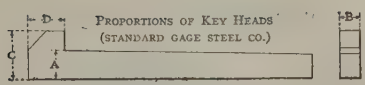
PRATT & WHITNEY KEY SYSTEM

Key No.	L	W	H	D	Key No.	L	W	H	D
1		1/16	3/32	1/16	22		1/4	3/8	1/4
2	1/2	3/32	1/16	3/32	23	1 3/8	5/16	1 5/32	5/16
3		1/8	3/16	1/8	F		3/8	9/16	3/8
4		3/32	9/64	3/32	24		1/4	3/8	1/4
5	5/8	1/8	3/16	1/8	25	1 1/2	5/16	1 5/32	5/16
6		5/32	15/64	5/32	G		3/8	9/16	3/8
7		1/8	3/16	1/8	51		1/4	3/8	1/4
8	3/4	5/32	15/64	5/32	52	1 3/4	5/16	1 5/32	5/16
9		3/16	9/32	3/16	53		3/8	9/16	3/8
10		5/32	15/64	5/32	26		3/16	9/32	3/16
11		3/16	9/32	3/16	27	2	1/4	3/8	1/4
12	7/8	7/32	21/64	7/32	28		5/16	1 5/32	5/16
A		1/4	3/8	1/4	29		3/8	9/16	3/8
13		3/16	9/32	3/16	54		1/4	3/8	1/4
14		7/32	21/64	7/32	55	2 1/4	5/16	1 5/32	5/16
15	1	1/4	3/8	1/4	56		3/8	9/16	3/8
B		5/16	1 5/32	5/16	57		7/16	21/32	7/16
16		3/16	9/32	3/16	58		5/16	1 5/32	5/16
17	1 1/8	7/32	21/64	7/32	59	2 1/2	3/8	9/16	3/8
18		1/4	3/8	1/4	60		7/16	21/32	7/16
C		5/16	1 5/32	5/16	61		1/2	3/4	1/2
19		3/16	9/32	3/16	30		3/8	9/16	3/8
20		7/32	21/64	7/32	31	3	7/16	21/32	7/16
21	1 1/4	1/4	3/8	1/4	32		1/2	3/4	1/2
D		5/16	1 5/32	5/16	33		9/16	27/32	9/16
E		3/8	9/16	3/8	34		5/8	1 5/16	5/8

TAPERS FOR KEYS, ETC., FROM $\frac{1}{16}$ TO 1 INCH PER FOOT. AMOUNT OF TAPERS FOR LENGTHS VARYING BY $\frac{1}{2}$ INCH

Taper per Foot	Length										
	1	1½	2	2½	3	3½	4	4½	5	5½	6
$\frac{1}{16}$	.0052	.0078	.0104	.0130	.0156	.0182	.0208	.0234	.0260	.0286	.0312
$\frac{1}{8}$	.0104	.0156	.0208	.0260	.0312	.0364	.0416	.0468	.0520	.0572	.0625
$\frac{3}{16}$	.0156	.0234	.0312	.0390	.0468	.0546	.0625	.0703	.0781	.0859	.0937
$\frac{1}{4}$	.0208	.0312	.0416	.0520	.0625	.0729	.0833	.0937	.1041	.1145	.1250
$\frac{5}{16}$	.0260	.0390	.0520	.0650	.0781	.0911	.1041	.1171	.1302	.1432	.1562
$\frac{3}{8}$	.0312	.0468	.0625	.0780	.0937	.1092	.1250	.1406	.1562	.1718	.1875
$\frac{7}{16}$	.0364	.0546	.0729	.0911	.1093	.1275	.1458	.1640	.1822	.2004	.2187
$\frac{1}{2}$	.0416	.0624	.0833	.1041	.1250	.1457	.1666	.1874	.2083	.2291	.2500
$\frac{9}{16}$	.0468	.0702	.0937	.1171	.1406	.1641	.1875	.2109	.2343	.2577	.2812
$\frac{5}{8}$	.0520	.0780	.1041	.1301	.1562	.1823	.2083	.2343	.2604	.2864	.3125
$\frac{11}{16}$	.0572	.0858	.1145	.1431	.1718	.2004	.2291	.2577	.2864	.3150	.3437
$\frac{3}{4}$	.0625	.0938	.1250	.1563	.1875	.2188	.2500	.2813	.3125	.3438	.3750
$\frac{13}{16}$	.0677	.1016	.1354	.1693	.2031	.2370	.2708	.3047	.3385	.3724	.4062
$\frac{7}{8}$	.0729	.1094	.1458	.1823	.2187	.2552	.2916	.3281	.3645	.4010	.4375
$\frac{15}{16}$	.0781	.1172	.1562	.1953	.2343	.2734	.3125	.3515	.3906	.4296	.4687
1	.0833	.1250	.1666	.2083	.2500	.2916	.3333	.3749	.4166	.4582	.5000

Taper per Foot	Length									
	6½	7	7½	8	8½	9	9½	10	10½	11	11½
$\frac{1}{16}$	.0338	.0364	.0390	.0416	.0442	.0468	.0494	.0520	.0546	.0572	.0598
$\frac{1}{8}$	.0677	.0729	.0781	.0833	.0885	.0937	.0989	.1041	.1093	.1145	.1197
$\frac{3}{16}$	.1015	.1093	.1171	.1250	.1328	.1406	.1484	.1562	.1640	.1718	.1796
$\frac{1}{4}$	.1354	.1458	.1562	.1666	.1770	.1875	.1979	.2083	.2187	.2291	.2395
$\frac{5}{16}$	.1692	.1822	.1952	.2083	.2213	.2343	.2473	.2604	.2734	.2864	.2994
$\frac{3}{8}$	.2031	.2187	.2343	.2500	.2656	.2812	.2968	.3125	.3281	.3437	.3593
$\frac{7}{16}$	.2369	.2552	.2734	.2916	.3098	.3281	.3463	.3645	.3827	.4010	.4192
$\frac{1}{2}$	.2708	.2916	.3124	.3333	.3541	.3750	.3958	.4166	.4374	.4583	.4791
$\frac{9}{16}$	.3046	.3281	.3515	.3750	.3984	.4218	.4452	.4687	.4921	.5156	.5390
$\frac{5}{8}$	.3385	.3645	.3905	.4166	.4426	.4687	.4947	.5208	.5468	.5729	.5989
$\frac{11}{16}$	.3723	.4010	.4296	.4583	.4869	.5156	.5442	.5729	.6015	.6302	.6588
$\frac{3}{4}$	.4063	.4375	.4688	.5000	.5313	.5625	.5938	.6250	.6563	.6875	.7188
$\frac{13}{16}$	.4401	.4739	.5078	.5416	.5755	.6093	.6432	.6770	.7109	.7447	.7786
$\frac{7}{8}$	.4739	.5104	.5468	.5833	.6197	.6562	.6926	.7291	.7655	.8020	.8384
$\frac{15}{16}$	.5078	.5468	.5859	.6250	.6640	.7031	.7422	.7812	.8203	.8593	.8984
1	.5416	.5833	.6249	.6666	.7082	.7500	.7917	.8333	.8750	.9166	.9583



PROPORTIONS OF KEYS HEADS—STANDARD GAGE STEEL CO.
(Dimensions in Inches)

A	B	C	D
1/8	1/8	1/4	7/32
5/32	5/32	5/16	9/32
1/4	1/4	7/16	3/8
5/16	5/16	1/2	7/16
3/8	3/8	5/8	1/2
7/16	7/16	11/16	9/16
1/2	1/2	3/4	5/8
9/16	9/16	7/8	11/16
5/8	5/8	1	3/4
11/16	11/16	1 1/16	13/16
3/4	3/4	1 1/8	7/8
13/16	13/16	1 3/16	15/16
7/8	7/8	1 1/4	1
15/16	15/16	1 5/16	1 1/16
1	1	1 3/8	1 1/8
1 1/16	1 1/16	1 7/16	1 3/16
1 1/8	1 1/8	1 1/2	1 1/4
1 3/16	1 3/16	1 9/16	1 5/16
1 1/4	1 1/4	1 5/8	1 3/8
1 5/16	1 5/16	1 11/16	1 7/16
1 3/8	1 3/8	1 3/4	1 1/2
1 7/16	1 7/16	1 13/16	1 9/16
1 1/2	1 1/2	1 7/8	1 5/8
1 9/16	1 9/16	2	1 11/16
1 5/8	1 5/8	2 1/8	1 3/4
1 11/16	1 11/16	2 1/4	1 13/16
1 3/4	1 3/4	2 3/8	1 7/8
1 13/16	1 13/16	2 1/2	1 15/16
1 7/8	1 7/8	2 5/8	2
1 15/16	1 15/16	2 3/4	2 1/16
2	2	2 7/8	2 1/8
2 1/16	2 1/16	3 1/8	2 3/16
2 1/8	2 1/8	3 1/4	2 1/4
2 3/16	2 3/16	3 3/8	2 5/16
2 1/4	2 1/4	3 1/2	2 3/8
2 5/16	2 5/16	3 5/8	2 7/16
2 3/8	2 3/8	3 3/4	2 1/2
2 7/16	2 7/16	3 7/8	2 9/16
2 1/2	2 1/2	4	2 5/8
2 9/16	2 9/16	4 1/8	2 11/16
2 5/8	2 5/8	4 1/4	2 3/4
2 11/16	2 11/16	4 3/8	2 13/16
2 3/4	2 3/4	4 1/2	2 7/8
2 13/16	2 13/16	4 5/8	2 15/16
2 7/8	2 7/8	4 3/4	3
2 15/16	2 15/16	4 3/4	3 1/16
3	3	4 7/8	3 1/8
		5	3 3/16
		5	3 1/4
		5 1/8	3 5/16
			3 1/2

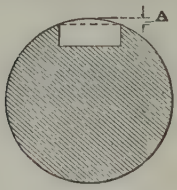
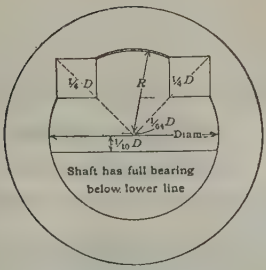


TABLE FOR FINDING TOTAL KEYWAY DEPTH

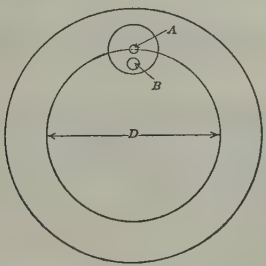
In the column marked "Size of Shaft" find the number representing the size; then to the right find the column representing the keyway to be cut and the decimal there is the distance *A*, which added to the depth of the keyway will give the total depth from the point where the cutter first begins to cut.

Size of Shaft	1/4 Keyway	5/16 Keyway	3/8 Keyway	7/16 Keyway	1/2 Keyway
1/2	0.0325	.....	.....	.....	.....
9/16	0.0289	.....	.....	.....	.....
5/8	0.0254	0.0413	.....	.....	.....
11/16	0.0236	0.0379	.....	.....	.....
3/4	0.022	0.0346	0.0511	.....	.....
13/16	0.0198	0.0314	0.0465	.....	.....
7/8	0.0177	0.0283	0.042	0.0583	.....
15/16	0.0164	0.0264	0.0392	0.0544	.....
1	0.0152	0.0246	0.0365	0.0506	0.067
1 1/16	0.0143	0.0228	0.0342	0.0476	0.0625
1 1/8	0.0136	0.021	0.0319	0.0446	0.0581
1 3/16	0.0131	0.0204	0.0304	0.0421	0.0551
1 1/4	0.0127	0.0198	0.029	0.0397	0.0522
1 5/16	0.0123	0.0191	0.0279	0.038	0.0499
1 3/8	0.012	0.0185	0.0268	0.0364	0.0477
1 7/16	0.0114	0.0174	0.0254	0.0346	0.0453
1 1/2	0.011	0.0164	0.024	0.0328	0.0429
1 9/16	0.0107	0.0158	0.0231	0.0309	0.0412
1 5/8	0.0105	0.0153	0.0221	0.0291	0.0395
1 11/16	0.0102	0.0147	0.0214	0.0282	0.0383
1 3/4	0.0099	0.0142	0.0207	0.0274	0.0371
1 13/16	0.0095	0.0136	0.0198	0.0265	0.0355
1 7/8	0.0093	0.013	0.019	0.0257	0.0339
1 15/16	0.009	0.0127	0.0184	0.025	0.0328
2	0.0088	0.0124	0.0179	0.0243	0.0317
2 1/16	0.0083	0.0117	0.0173	0.0236	0.0308
2 1/8	0.0078	0.0111	0.0168	0.0229	0.0299
2 3/16	0.0073	0.0109	0.0163	0.0222	0.0291
2 1/4	0.007	0.0107	0.0159	0.0216	0.0282
2 5/16	0.0068	0.0104	0.0155	0.0209	0.0274
2 3/8	0.0066	0.0102	0.0152	0.0202	0.0267
2 7/16	0.0064	0.01	0.0149	0.0198	0.026
2 1/2	0.0063	0.0098	0.0146	0.0194	0.0253



The Kennedy Key

This Key was designed by Julian Kennedy of Pittsburgh, Pa. and is used in heavy work such as gearing for rolling mills. The keys are square and $\frac{1}{4}$ the diameter, the sides being parallel and a good fit while the top of key is tapered $\frac{1}{8}$ in. per foot. The keys are set so that lines drawn diagonally through the corners will meet at the center of the shaft. After boring the hub is offset $\frac{1}{64}$ the diameter and rebored to the same radius, relieving the top of the bore. This relieves the sides so that the full bearing usually begins at $\frac{1}{10}$ the diameter below the center, as shown. Up to 6 in. shafts, single keys are generally used, above 6 in. the two keys as shown.



The Nordberg Key

The Nordberg Key is round with a taper of $\frac{1}{16}$ in. per foot. The large diameter is approximately $\frac{1}{4}$ the diameter of the shaft, up to 6 inches. Above this the Key is about $\frac{1}{6}$ the shaft diameter. In practice the small hole *A* is first drilled at the joint, then a hole *B*, as large as convenient without exceeding the key diameter. This prevents the full size drill from "running," or crowding into the cast iron of the hub.

TAPERS AND DOVETAILS

MEASURING TAPERS

An Accurate Taper Gage

THE gage illustrated in Fig. 1 is an exceedingly accurate device for the gaging of tapers.

It is evident that if two round disks of unequal diameter are placed on a surface plate a certain distance apart, two straight-edges touching these two disks will represent a certain taper. It is also evident that with the measuring instruments now in use it is a simple matter to measure accurately the diameters of the two disks, and the distance these disks are apart. These three dimensions accurately and positively determine the taper represented by the straight-edges touching the rolls. If a record is made of these

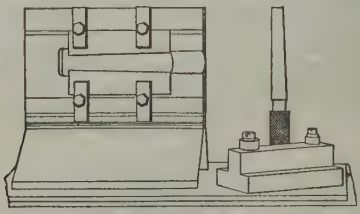


FIG. 1.—Accurate Taper Gage

three dimensions these conditions can be reproduced at any time, thus making it possible to duplicate a taper piece even though the part may not at the time be accessible.

The formulas on the following pages may be of service in connection with a gage of this character:

Formulas for Use in Connection with Taper Gage

To find center distance (l), refer to Fig. 2.

$$l = \frac{R - r}{t}\sqrt{1 + t^2}$$

To find disk diameters, refer to Fig. 3.

$$r = \frac{a}{L}\left[\sqrt{L^2 + (b - a)^2} + (b - a)\right]$$

Dia. small disk $= 2r$

$$R = \frac{b}{L}\left[\sqrt{L^2 + (b - a)^2} - (b - a)\right]$$

Dia. large disk $= 2R$

To find taper per foot (T), refer to Fig. 4.

$$T = 24\left(\frac{R - r}{\sqrt{l^2 - (R - r)^2}}\right)$$

To find width of opening at ends, refer to Fig. 5.

$$a = r\sqrt{\frac{l - (R - r)}{l + (R - r)}}$$

Width of opening at small end = 2 a.

$$b = R\sqrt{\frac{l + (R - r)}{l - (R - r)}}$$

Width of opening at large end = 2 b.

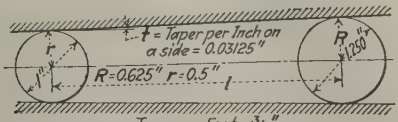


FIG. 2

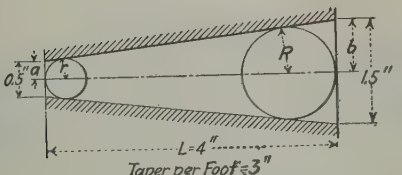


FIG. 3

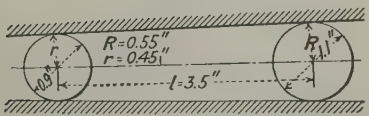


FIG. 4

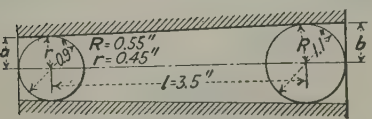


FIG. 5
Applications of Taper Gage

Applications of Formulas

To Find Center Distance Between Disks

Suppose there are two disks as shown in Fig. 2, whose diameters are respectively $1\frac{1}{4}$ and 1 inch. It is desired to construct a taper of $\frac{3}{4}$ to the foot, and the center distance l between disks must be determined in order that the gage jaws when touching both disks shall give that taper.

Let R = radius of large disk, or 0.625 inch.
r = radius of small disk, or 0.500 inch.
t = taper per inch on side, or

$$\frac{0.750}{24} = 0.03125 \text{ inch.}$$

Then

$$l = \frac{R - r}{t}\sqrt{1 + t^2} =$$

$$\frac{0.125}{0.03125}\sqrt{1.000976} = 4 \times 1.0005 = 4.002 \text{ inches.}$$

To Find Disk Diameters

Suppose the gage jaws are to be set as in Fig. 3 for a 3-inch per foot taper whose length is to be 4 inches. The small end is to be exactly $\frac{1}{2}$ inch and the large end for this taper will, therefore, be $1\frac{1}{2}$ inches. What diameter must the disks be made so that when the jaws are in contact with them and the distance L over the disks measures 4 inches, the taper will be exactly 3 inches per foot? Here a represents one-half the width of opening at the small end, and b one-half the width of opening at the large end. The radius of the small disk may be found by the formula:

$$r = \frac{a}{L}\left\{\sqrt{L^2 + (b - a)^2} + (b - a)\right\}.$$

Then

$$r = \frac{0.250}{4}\left(\sqrt{16 + 0.25} + 0.5\right)$$

$$= 0.0625(4.0311 + 0.5) = 0.2832$$

Diameter small disk = 0.2832 inch × 2 = 0.5664 inch.
For the large disk:

$$R = \frac{b}{L}\left\{\sqrt{L^2 + (b - a)^2} - (b - a)\right\}$$

Then

$$R = \frac{0.75}{4}\left(\sqrt{16 + 0.25} - 0.5\right)$$

$$= 0.1875\ (4.0311 - 0.5) = 0.6621.$$

Diameter large disk = 0.6621 inch × 2 = 1.3242 inches.

To Find Taper Per Foot

In duplicating a taper the gage jaws may be set to the model, and, by placing between the jaws a pair of disks whose diameters are known, the taper per foot may be readily found. For example, the jaws in Fig. 4 are set to a certain model, two disks 0.9 and 1.1 inch diameter are placed between them and the distance over the disks measured, from which dimension l (which is 3.5 inches) is readily found by subtracting half the diameters of the disks. Here l represents the center distance as in Fig. 2. To determine the taper per foot which may be represented by T, the formula is:

$$T = 24\left(\frac{R - r}{\sqrt{l^2 - (R - r)^2}}\right)$$

Then

$$T = 24\left(\frac{0.1}{\sqrt{12.25 - 0.01}}\right) = 24\left(\frac{0.1}{3.4985}\right) = 0.684.$$

Taper per foot = 0.684 inch.

To Find Width of Opening at Ends

If, with the ends of the gage jaws flush with a line tangent to the disk peripheries as in Fig. 5, it is required to find the width of the opening at the small end where a represents one-half that width, the following formula may be applied, the disks being as in the last example 0.9 and 1.1 inch diameter respectively, and the center distance 3.5 inches:

$$a = r\sqrt{\frac{l - (R - r)}{l + (R - r)}}$$

Then

$$a = 0.45\sqrt{\frac{3.5 - (.55 - .45)}{3.5 + (.55 - .45)}}$$

$$= 0.45\sqrt{\frac{3.4}{3.9}} = 0.45\sqrt{.94444} = .4373$$

0.4373 inch $\times$ 2 = 0.8746 inch width of opening at small end of gage.

Similarly the width of opening at the large end of the gage may be found as follows, where b = half the width of the large end.

$$b = R\sqrt{\frac{l + (R - r)}{l - (R - r)}}$$

Then

$$b = 0.55\sqrt{\frac{3.5 + (.55 - .45)}{3.5 - (.55 - .45)}}$$

$$= 0.55\sqrt{\frac{3.6}{3.4}} = 0.55\sqrt{1.02899} = .56595$$

0.56595 inch $\times$ 2 = 1.1319 inch = width of opening at large end.

BROWN & SHARPE TAPERS—TAPER ½-INCH PER FOOT EXCEPT NO. 10, WHICH IS 0.5161-INCH PER FOOT
(Dimensions in Inches)

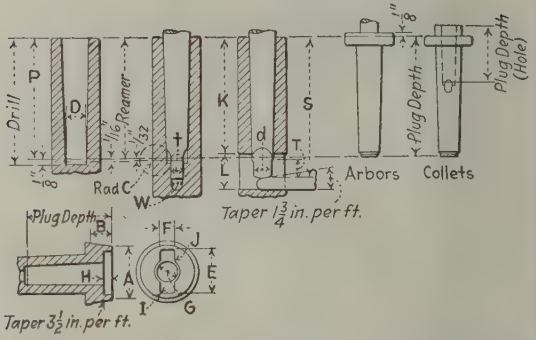
No. of Taper	Diam. of Plug at Small End D	Plug Depth P			Keyway from Bnd of Spindle K	Shank Depth S	Length of Keyway L	Width of Keyway W	Length of Arbor Tongue T	Diameter of Arbor Tongue d	Thickness of Arbor Tongue t	Radius of Tongue Circle c	Radius of Tongue at a a	Limit for Tongue to Project through Test Tool
		B. & S. Standard	Milling-Mach. Standard	Miscellaneous										
1	0.200	1 5/16			1 1/16	1 1/16	3/4	0.135	1 1/16	0.170	1/8	3/16	0.030	0.003
2	0.250	1 7/16			1 11/64	1 5/32	7/8	0.166	1 1/4	0.220	3/16	3/16	0.030	0.003
3	0.312	1 1/2		1 3/4	1 13/64	1 7/32	1	0.197	1 5/16	0.282	1/4	3/16	0.040	0.003
				2	1 13/64	2 5/32		0.197	1 5/16	0.282	1/4	3/16	0.040	0.003
4	0.350		1 1/4		1 21/64	1 11/32	1 1/16	0.228	1 7/16	0.320	5/32	3/16	0.050	0.003
		1 11/16			1 41/64	2 3/32	1 1/4	0.228	1 7/16	0.320	5/32	3/16	0.050	0.003
5	0.450		1 3/4		1 11/16	2 1/16	1 3/4	0.260	2 3/16	0.420	1/4	1/4	0.060	0.003
				2	1 11/16	2 1/16		0.260	2 3/16	0.420	1/4	1/4	0.060	0.003
6	0.500	2 1/16			2 1/16	2 3/16	2 1/16	0.291	2 7/16	0.460	9/32	1/4	0.060	0.005
		2 3/16		2 1/2	2 1/16	2 7/8		0.291	2 7/16	0.460	9/32	1/4	0.060	0.005
7	0.600	2 7/8			2 13/16	3 3/16	2 1/16	0.322	3 1/16	0.560	1/16	5/16	0.070	0.005
				3	2 13/16	3 13/16		0.322	3 1/16	0.560	5/16	5/16	0.070	0.005
8	0.750	3 1/8			3 1/16	4 1/16	1	0.353	3 1/2	0.710	11/64	5/16	0.080	0.005

9	0.900	$4\frac{1}{4}$	4		$3\frac{7}{8}$	$4\frac{5}{8}$	$1\frac{1}{8}$	0.385	$\frac{9}{16}$	0.860	$\frac{3}{8}$	$\frac{7}{16}$	0.100	0.005
					$4\frac{1}{8}$	$4\frac{7}{8}$	$1\frac{1}{8}$	0.385	$\frac{9}{16}$	0.860	$\frac{3}{8}$	$\frac{7}{16}$	0.100	0.005
		5			$4\frac{27}{32}$	$5\frac{23}{32}$	$1\frac{5}{16}$	0.447	$\frac{21}{32}$	1.010	$\frac{7}{16}$	$\frac{7}{16}$	0.110	0.005
10	1.0446		$5\frac{11}{16}$		$5\frac{17}{32}$	$6\frac{13}{32}$	$1\frac{5}{16}$	0.447	$\frac{21}{32}$	1.010	$\frac{7}{16}$	$\frac{7}{16}$	0.110	0.005
				$6\frac{7}{32}$	$6\frac{1}{16}$	$6\frac{15}{16}$	$1\frac{5}{16}$	0.447	$\frac{21}{32}$	1.010	$\frac{7}{16}$	$\frac{7}{16}$	0.110	0.005
11	1.250	$5\frac{15}{16}$			$5\frac{25}{32}$	$6\frac{21}{32}$	$1\frac{5}{16}$	0.447	$\frac{21}{32}$	1.210	$\frac{7}{16}$	$\frac{1}{2}$	0.130	0.005
			$6\frac{3}{4}$		$6\frac{29}{32}$	$7\frac{15}{32}$	$1\frac{6}{16}$	0.447	$\frac{21}{32}$	1.210	$\frac{7}{16}$	$\frac{1}{2}$	0.130	0.005
12	1.500	$7\frac{1}{8}$	$7\frac{1}{8}$		$6\frac{15}{16}$	$7\frac{15}{16}$	$1\frac{1}{2}$	0.510	$\frac{3}{4}$	1.460	$\frac{1}{2}$	$\frac{1}{2}$	0.150	0.005
13	1.750	$7\frac{3}{4}$		$6\frac{1}{4}$	$7\frac{9}{16}$	$8\frac{9}{16}$	$1\frac{1}{2}$	0.510	$\frac{3}{4}$	1.710	$\frac{1}{2}$	$\frac{5}{8}$	0.170	0.010
14	2.00	$8\frac{1}{4}$	$8\frac{1}{4}$		$8\frac{1}{32}$	$9\frac{1}{32}$	$1\frac{11}{16}$	0.572	$\frac{27}{32}$	1.960	$\frac{9}{16}$	$\frac{3}{4}$	0.190	0.010
15	2.25	$8\frac{3}{4}$			$8\frac{17}{32}$	$9\frac{21}{32}$	$1\frac{11}{16}$	0.572	$\frac{27}{32}$	2.210	$\frac{9}{16}$	$\frac{7}{8}$	0.210	0.010
16	2.50	$9\frac{1}{4}$			9	$10\frac{1}{4}$	$1\frac{7}{8}$	0.635	$\frac{15}{16}$	2.450	$\frac{5}{8}$	1	0.230	0.010
17	2.75	$9\frac{3}{4}$												
18	3.00	$10\frac{1}{4}$												

* "B & S Standard" plug depths are not used in all cases.

† Special lengths of keyway are used instead of standard lengths in some places. Standard lengths need not be used when keyway is for driving only and not for admitting key to force out tool.

BROWN & SHARPE TAPERS



See pages 570 and 571 for table of Brown & Sharpe tapers.

BROWN & SHARPE TAPERS
DIMENSIONS OF MILLING-MACHINE SPINDLES
(Taper-Nose)

*A**	*B*	*E*	*F*	*G*	*H*	*I*	*J*
3.045	2	$2\frac{1}{2}$	1	$1\frac{3}{8}$	$\frac{5}{8}$	$\frac{3}{16}$	$\frac{1}{8}$
5.255	$2\frac{1}{8}$	$4\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{13}{32}$	$\frac{7}{8}$	$\frac{1}{4}$	$\frac{1}{4}$

* Diameter at sharp corner.

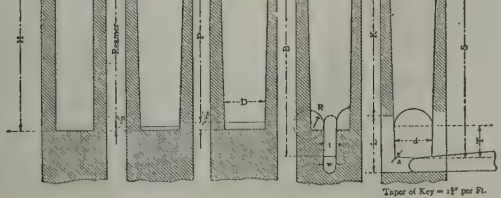
THE JARNO TAPER

Taper per foot = 0.6 inch. Taper per inch = 0.05 inch.

Diam. large end = $\frac{\text{No. of taper.}}{8}$. Diam. small end = $\frac{\text{No. of taper}}{10}$.

Length of taper = $\frac{\text{No. of taper}}{2}$.

While the majority of American tool builders use the Brown & Sharpe taper in their milling-machine spindles, and the Morse taper in their lathes and drilling machines, a number of firms have adopted the "Jarno" taper. In this system, the taper of which is 0.6 inch per foot or 1 in 20, the number of the taper is the key by which all the dimensions are immediately determined. That is the number of the taper is the number of tenths of an inch in diameter at the small end, the number of eighths of an inch at the large end and the number of halves of an inch in length or depth. For example: the No. 6 taper is $\frac{6}{8}$ ($\frac{3}{4}$)-inch diameter at large end, $\frac{6}{10}$ diameter at the small end and $\frac{6}{2}$ (3) inches in length. Similarly, the No. 16 taper is $\frac{16}{8}$, or 2-inch diameter at the large end; $\frac{16}{10}$ or 1.6-inch at the small end; $\frac{16}{2}$ or 8 inches in length.



Morse Standard Tapers

MORSE TAPERS

No. of Taper	Dia. of Plug at Small End D	Dia. at End of Socket A	Standard Plug Depth P	Whole Length of Shank B	Depth of Hole H	End of Socket to Keyway K	Length of Keyway L	Width of Keyway W	Length of Tongue T	Dia. of Tongue d	Thickness of Tongue t	Radius of Mill for Tongue R	Radius of Tongue a	Shank Depth S	Taper per Foot	Taper per Inch	No. of Key
0	.252	.356	2	$2\frac{1}{32}$	$2\frac{1}{32}$	$1\frac{5}{16}$	$\frac{9}{16}$	.160	$\frac{1}{4}$	.235	$\frac{5}{32}$	$\frac{5}{32}$	.04	$2\frac{7}{32}$	.625	.05208	0
1	.369	.475	$2\frac{1}{4}$	$2\frac{9}{16}$	$2\frac{3}{16}$	$2\frac{1}{16}$	$\frac{3}{4}$	.213	$\frac{3}{8}$	.343	$\frac{13}{64}$	$\frac{8}{16}$	.05	$2\frac{7}{16}$	.600	.05	1
2	.572	.7	$2\frac{7}{16}$	$3\frac{1}{8}$	$2\frac{5}{8}$	$2\frac{1}{4}$	1	.26	$\frac{7}{16}$	$\frac{17}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	.06	$2\frac{15}{16}$	.602	.05016	2
3	.778	.938	$3\frac{1}{16}$	$3\frac{7}{8}$	$3\frac{1}{4}$	$3\frac{1}{16}$	$1\frac{3}{16}$	.322	$\frac{9}{16}$	$\frac{23}{32}$	$\frac{5}{16}$	$\frac{9}{32}$	.08	$3\frac{1}{16}$	.602	.05016	3
4	1.02	1.231	$4\frac{1}{16}$	$4\frac{7}{8}$	$4\frac{1}{8}$	$3\frac{7}{8}$	$1\frac{1}{4}$	.478	$\frac{5}{8}$	$\frac{31}{32}$	$\frac{15}{32}$	$\frac{5}{16}$	.10	$4\frac{5}{8}$	.623	.05191	4
5	1.475	1.748	$5\frac{1}{16}$	$6\frac{1}{8}$	$5\frac{1}{4}$	$4\frac{15}{16}$	$1\frac{1}{2}$	.635	$\frac{3}{4}$	$1\frac{13}{32}$	$\frac{5}{8}$	$\frac{3}{8}$	.12	$5\frac{7}{8}$	.630	.0525	5
6	2.116	2.494	$7\frac{1}{4}$	$8\frac{9}{16}$	$7\frac{3}{8}$	7	$1\frac{1}{2}$	.76	$1\frac{1}{16}$	2	$\frac{3}{4}$	$\frac{1}{2}$	.15	$8\frac{1}{4}$	.626	.05216	6
7	2.75	3.27	10	$11\frac{5}{8}$	$10\frac{1}{8}$	$9\frac{1}{4}$	$2\frac{5}{8}$	1.135	$1\frac{3}{8}$	$2\frac{5}{8}$	$1\frac{1}{8}$	$\frac{3}{4}$	.18	$11\frac{1}{4}$	.625	.05208	7

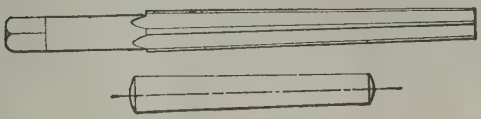
OTHER TAPERS

A number of other tapers are used, but to such a limited extent that full tables are not warranted. One, the Reed taper, used on lathes, has the same taper as the Jarno, 1 in 20, but differs both in diameters and lengths used.

The Standard Tool Company has two tapers, known as the standard and short tapers. These vary from 0.600 to 0.630 inch per foot.

The Sellers taper is 0.75 inch per foot and has a keyway the whole length of the taper, but no tang.

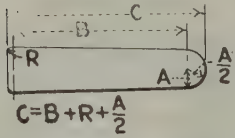
TAPER PINS AND REAMERS



TAPER REAMERS AND PINS
(PRATT & WHITNEY CO.)
Taper = $\frac{1}{4}$ inch per foot or 0.0208 inch per inch

Size. No.	Dia. of Small End of Reamer	Dia. of Large End of Reamer	Length of Flute	Total Length of Reamer	Size Drill for Reamer	Longest Limit Length of Pin	Dia. of Large End of Pin	Approx. Fractional Size at Large End of Pin
0	0.135″	.162″	$1\frac{5}{16}$″	2″	28	1″	.156″	$\frac{5}{32}$″
1	.146″	.179″	$1\frac{9}{16}$″	$2\frac{3}{16}$″	25	$1\frac{1}{4}$″	.172″	$\frac{11}{64}$″
2	.162″	.200″	$1\frac{11}{16}$″	$2\frac{11}{16}$″	19	$1\frac{1}{2}$″	.193″	$\frac{3}{16}$″
3	.183″	.226″	$2\frac{1}{16}$″	3″	12	$1\frac{3}{4}$″	.219″	$\frac{7}{32}$″
4	.208″	.257″	$2\frac{3}{16}$″	$3\frac{1}{16}$″	3	2″	.250″	$\frac{1}{4}$″
5	.240″	.300″	$2\frac{3}{8}$″	$4\frac{3}{16}$″	$\frac{1}{4}$	$2\frac{1}{4}$″	.289″	$\frac{9}{32}$″
6	.279″	.354″	$3\frac{3}{8}$″	5″	$\frac{5}{16}$	$3\frac{1}{4}$″	.341″	$\frac{11}{32}$″
7	.331″	.423″	$4\frac{7}{16}$″	$6\frac{1}{16}$″	$\frac{11}{32}$	$3\frac{3}{4}$″	.409″	$\frac{13}{32}$″
8	.398″	.507″	$5\frac{1}{4}$″	$7\frac{1}{16}$″	$\frac{3}{8}$	$4\frac{1}{2}$″	.492″	$\frac{1}{2}$″
9	.482″	.609″	$6\frac{1}{4}$″	$8\frac{1}{16}$″	$\frac{13}{32}$	$5\frac{1}{4}$″	.591″	$\frac{19}{32}$″
10	.581″	.727″	7″	$9\frac{1}{16}$″	$\frac{7}{16}$	6″	.706″	$\frac{23}{32}$″
11	.706″	.878″	$8\frac{1}{4}$″	$11\frac{1}{16}$″	$\frac{29}{64}$	$7\frac{1}{4}$″	.857″	$\frac{55}{64}$″
12	.842″	1.050″	10″	$13\frac{3}{16}$″	$\frac{15}{32}$	$8\frac{1}{4}$″	1.013″	$1\frac{1}{32}$″
13	1.009″	1.259″	12″	16″	$1\frac{1}{64}$	$10\frac{3}{4}$″	1.233″	$1\frac{1}{64}$″

These reamer sizes are so proportioned that each overlaps the size smaller about $\frac{1}{2}$ inch.



BROWN & SHARPE MFG. CO.'S TAPER PINS

(Tool Steel, Taper $\frac{1}{4}$-Inch per Foot) (Dimensions in Inches)

No. of pin	00	0	1	2	3	4
Diam. at small end *A*	0.118	0.135	0.146	0.162	0.183	0.208
Approx. diam. small end	$\frac{1}{8}$	$\frac{9}{64}$	$\frac{9}{64}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$
Diam. of shaft	$\frac{9}{32}$–$\frac{5}{16}$	$\frac{3}{8}$–$\frac{7}{16}$	$\frac{1}{2}$–$\frac{9}{16}$	$\frac{5}{8}$–$\frac{11}{16}$	$\frac{3}{4}$–$\frac{13}{16}$	$\frac{7}{8}$–$\frac{15}{16}$
Radius of corner *R*	0.01	0.01	0.01	0.02	0.02	0.02

No. of pin	5	6	7	8	9	10
Diam. at small end *A*	0.240	0.279	0.331	0.398	0.482	0.581
Approx. diam. small end	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{11}{32}$	$\frac{13}{32}$	$\frac{15}{32}$	$\frac{19}{32}$
Diam. of shaft	1–$1\frac{1}{8}$	$1\frac{3}{16}$–$1\frac{5}{16}$	$1\frac{3}{8}$–$1\frac{1}{2}$	$1\frac{9}{16}$–$1\frac{11}{16}$	$1\frac{3}{4}$–$1\frac{7}{8}$	$1\frac{15}{16}$–$2\frac{1}{16}$
Radius of corner *R*	0.02	0.03	0.03	0.04	0.04	0.05

The flat head and rounded point remove all doubt as to which is the large end of the pin. Lengths vary by $\frac{1}{8}$-inch increments for general use.

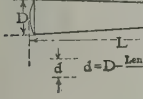
TAPER OF COCK PLUGS

While there is no standard taper for cock plugs, a taper of $1\frac{1}{8}$ inches per foot is used in many cases.

Table of Drill Sizes for Taper Pins

Drill Sizes for Taper Pins

The table gives the drill sizes for taper pins ranging in lengths by $\frac{1}{4}$ inch from No. 0, $\frac{3}{4}$ inch long, to No. 10, 6 inches long. The diameter of the small end of the pin for each length is given in the fourth column with the drill size in the fifth column. Radius of rounded ends varies from $\frac{1}{8}$ to 2 diameters of pin, usually measured at the large end.



No. Pin	L	D	d	No. of Drill
0	$\frac{3}{4}$″	0.156″	0.1404″	28
0	1″	0.156″	0.1352″	29
1	$\frac{3}{4}$″	0.172″	0.1564″	22
1	1″	0.172″	0.1512″	24
1	1$\frac{1}{4}$″	0.172″	0.146 ″	26
2	$\frac{3}{4}$″	0.193″	0.1774″	16
2	1″	0.193″	0.1722″	17
2	1$\frac{1}{4}$″	0.193″	0.167 ″	18
2	1$\frac{1}{2}$″	0.193″	0.1618′	20
3	$\frac{3}{4}$″	0.219″	0.2034″	6
3	1″	0.219″	0.1982″	8
3	1$\frac{1}{4}$″	0.219″	0.193 ″	10
3	1$\frac{1}{2}$″	0.219″	0.1878″	12
3	1$\frac{3}{4}$″	0.219″	0.1825″	14
4	$\frac{3}{4}$″	0.250″	0.2344″	$\frac{15}{64}$″
4	1″	0.250″	0.2292″	$\frac{15}{64}$″
4	1$\frac{1}{4}$″	0.250″	0.224 ″	I
4	1$\frac{1}{2}$″	0.250″	0.2187″	2
4	1$\frac{3}{4}$″	0.250 ′	0.2135″	3
4	2 ″	0.250″	0.2083″	4
5	$\frac{3}{4}$″	0.289″	0.2734″	$\frac{17}{64}$″
5	1″	0.289″	0.2682″	$\frac{17}{64}$″
5	1$\frac{1}{4}$″	0.289″	0.263 ″	$\frac{17}{64}$″
5	1$\frac{1}{2}$″	0.289″	0.2577″	$\frac{1}{4}$″
5	1$\frac{3}{4}$″	0.289″	0.2525″	$\frac{1}{4}$″
5	2 ″	0.289″	0.2473″	$\frac{1}{4}$″
5	2$\frac{1}{4}$″	0.289″	0.2421″	$\frac{15}{64}$″
6	$\frac{3}{4}$″	0.341″	0.3254″	$\frac{21}{64}$″
6	1″	0.341″	0.3201″	$\frac{21}{64}$″
6	1$\frac{1}{4}$″	0.341″	0.315 ″	$\frac{5}{16}$″
6	1$\frac{1}{2}$″	0.341″	0.310 ″	$\frac{5}{16}$″
6	1$\frac{3}{4}$″	0.341″	0.3045″	$\frac{19}{64}$″
6	2 ″	0.341″	0.2994″	$\frac{19}{64}$″
6	2$\frac{1}{4}$″	0.341″	0.2941″	$\frac{19}{64}$″
6	2$\frac{1}{2}$″	0.341″	0.2889″	$\frac{9}{32}$″
6	2$\frac{3}{4}$″	0.341″	0.2837″	$\frac{9}{32}$″
6	3 ″	0.341″	0.2785″	$\frac{9}{32}$″
6	3$\frac{1}{4}$″	0.341″	0.2733″	$\frac{17}{64}$″
7	1 ″	0.409″	0.3881″	$\frac{25}{64}$″
7	1$\frac{1}{4}$″	0.409″	0.3829″	$\frac{25}{64}$″
7	1$\frac{1}{2}$″	0.409″	0.3777″	$\frac{3}{8}$″
7	1$\frac{3}{4}$″	0.409″	0.3725″	$\frac{3}{8}$″
7	2 ″	0.409″	0.3673″	$\frac{3}{8}$″
7	2$\frac{1}{4}$″	0.409″	0.3621″	$\frac{23}{64}$″
7	2$\frac{1}{2}$″	0.409″	0.3569″	$\frac{23}{64}$″
7	2$\frac{3}{4}$″	0.409″	0.3517″	$\frac{23}{64}$″
7	3 ″	0.409″	0.3465″	$\frac{11}{32}$″
7	3$\frac{1}{4}$″	0.409″	0.3413″	$\frac{11}{32}$″
7	3$\frac{1}{2}$″	0.409″	0.3361″	$\frac{11}{32}$″
7	3$\frac{3}{4}$″	0.409″	0.3309″	$\frac{11}{32}$″
8	1$\frac{1}{4}$″	0.492″	0.466 ″	$\frac{15}{32}$″
8	1$\frac{1}{2}$″	0.492″	0.4608″	$\frac{15}{32}$″
8	1$\frac{3}{4}$″	0.492″	0.4555″	$\frac{29}{64}$″
8	2 ″	0.492″	0.4503″	$\frac{29}{64}$″
8	2$\frac{1}{4}$″	0.492″	0.4451″	$\frac{29}{64}$″
8	2$\frac{1}{2}$″	0.492′	0.4399″	$\frac{7}{16}$″
8	2$\frac{3}{4}$″	0.492″	0.4347″	$\frac{7}{16}$″
8	3 ″	0.492″	0.4295″	$\frac{7}{16}$″
8	3$\frac{1}{4}$″	0.492″	0.4243″	$\frac{27}{64}$″
8	3$\frac{1}{2}$″	0.492″	0.4191″	$\frac{27}{64}$″
8	3$\frac{3}{4}$″	0.492″	0.4139″	$\frac{27}{64}$″
8	4 ″	0.492″	0.4087″	$\frac{13}{32}$″
8	4$\frac{1}{4}$″	0.492″	0.4035″	$\frac{13}{32}$″
8	4$\frac{1}{2}$″	0.492″	0.3982″	$\frac{13}{32}$″
9	1$\frac{1}{2}$″	0.591″	0.5597″	$\frac{9}{16}$″
9	1$\frac{3}{4}$″	0.591″	0.5545″	$\frac{35}{64}$″
9	2 ″	0.591″	0.5493″	$\frac{35}{64}$″
9	2$\frac{1}{4}$″	0.591″	0.5441″	$\frac{35}{64}$″
9	2$\frac{1}{2}$″	0.591″	0.5389″	$\frac{35}{64}$″
9	2$\frac{3}{4}$″	0.591″	0.5337″	$\frac{17}{32}$″
9	3 ″	0.591″	0.5285″	$\frac{17}{32}$″
9	3$\frac{1}{4}$″	0.591″	0.5233″	$\frac{17}{32}$″
9	3$\frac{1}{2}$″	0.591″	0.5181″	$\frac{17}{32}$″
9	3$\frac{3}{4}$″	0.591″	0.5129″	$\frac{33}{64}$″
9	4 ″	0.591″	0.5077″	$\frac{33}{64}$″
9	4$\frac{1}{4}$″	0.591″	0.5025″	$\frac{33}{64}$″
9	4$\frac{1}{2}$″	0.591″	0.4972″	$\frac{33}{64}$″
9	4$\frac{3}{4}$″	0.591″	0.4920″	$\frac{33}{64}$″
9	5 ″	0.591″	0.4868″	$\frac{31}{64}$″
9	5$\frac{1}{4}$″	0.591″	0.4816″	$\frac{31}{64}$″
9	5$\frac{1}{2}$″	0.591″	0.4764″	$\frac{31}{64}$″
10	1$\frac{1}{2}$″	0.706″	0.6747″	$\frac{43}{64}$″
10	1$\frac{3}{4}$″	0.706″	0.6695″	$\frac{43}{64}$″
10	2 ″	0.706″	0.6643″	$\frac{43}{64}$″
10	2$\frac{1}{4}$″	0.706″	0.6591″	$\frac{21}{32}$″
10	2$\frac{1}{2}$″	0.706″	0.6539″	$\frac{21}{32}$″
10	2$\frac{3}{4}$″	0.706″	0.6487″	$\frac{21}{32}$″
10	3 ″	0.706″	0.6435″	$\frac{41}{64}$″
10	3$\frac{1}{4}$″	0.706″	0.6383″	$\frac{41}{64}$″
10	3$\frac{1}{2}$″	0.706″	0.6331″	$\frac{41}{64}$″
10	3$\frac{3}{4}$″	0.706″	0.6278″	$\frac{41}{64}$″
10	4 ″	0.706″	0.6226″	$\frac{41}{64}$″
10	4$\frac{1}{4}$″	0.706″	0.6174″	$\frac{41}{64}$″
10	4$\frac{1}{2}$″	0.706″	0.6122″	$\frac{41}{64}$″
10	4$\frac{3}{4}$″	0.706″	0.6078″	$\frac{41}{64}$″
10	5 ″	0.706″	0.6018″	$\frac{41}{64}$″
10	5$\frac{1}{4}$″	0.706″	0.5966″	$\frac{41}{64}$″
10	5$\frac{1}{2}$″	0.706″	0.5914″	$\frac{41}{64}$″
10	5$\frac{3}{4}$″	0.706″	0.5862″	$\frac{41}{64}$″
10	6 ″	0.706″	0.581 ″	$\frac{41}{64}$″

Taper is $\frac{1}{4}$ inch per foot—sizes from 5–0 to 0000 = 0.094; 0000 = 0.109; 000 = 0.125; 00 = 0.141 at large end.

STANDARD TAPER PINS USED BY THE U. S. ORDNANCE DEPARTMENT

The accompanying tables show the standard taper and split pin used by the Ordnance Department of the U. S. Army as revised up to July 20, 1912. The first table shows the standard taper pins and the retaining split pins used in the end. The pins are ¼-inch taper per foot. They have tapered head and point to allow for upsetting, either in driving or removing pins from the work.

The first table gives the number of the pin and the diameter at the small end in the first two columns. The next three columns show the sizes of the shaft and collars in which these pins are used, while the last two columns show the split pins which are used in some cases on the small end of the taper pin to prevent accidental withdrawal from the hole.

The second table shows the dimensions of the standard split pin used in connection with the taper pins, and gives the diameter and the length manufactured. The tapered points are shown by the drawing to be the length of the diameter of the split pin, with the small end of the taper 0.75 of the diameter.

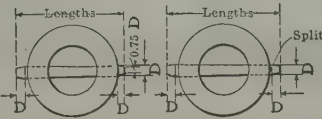
STANDARD TAPER PINS

0.25 per Ft. Taper and Retaining Split Pins

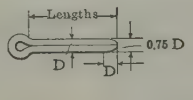
TAPER PINS		WORK			SPLIT PINS	
DIA. AT SMALL END		USED IN SHAFTS		COLLARS	DIAM.	LENGTH
Number	D	Min. Diam.	Max. Diam.	Max. Diam.		
	0.0625		0.3	0.75		
	0.09375	0.3	0.5	1		
0	0.135	0.5	0.75	1.125	0.0468	0.3125
2	0.162	0.75	1	1.625	0.0625	0.375
4	0.208	1	1.5	2.125	0.0781	0.4375
6	0.279	1.5	2	3.25	0.09375	0.5
8	0.398	2	3	4.875	0.125	0.75
10	0.581	3	4.5	6.625	0.156	1
12	0.842	4.5	6.5	9.625	0.203	1.25

STANDARD SPLIT PINS

DIAM.	LENGTHS MANUFACTURED														
0.0468	0.3125	0.5													
0.0625	0.375	0.5625	0.75												
0.0781	0.4375	0.625	0.8125	1				ALL PINS BELOW THIS LINE							
0.09375	0.5	0.75	1	1.25	1.5	1.75	2	ARE COMMERCIAL SIZES							
0.125	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5						
0.156	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5						
0.203		0.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3				
0.25			1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4
0.375					1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4
0.5	Also 5 and 6 inch						2	2.25	2.5	2.75	3	3.25	3.5	3.75	4
0.625	Also 5 and 6 inch										3	3.25	3.5	3.75	4



D = Nominal Diam. or Diam. of Hole to Receive Pin



TAPERS FROM $\frac{1}{16}$ TO $1\frac{1}{4}$ INCH PER FOOT
AMOUNT OF TAPER FOR LENGTHS UP TO 24 INCHES

Length of Tapered Portion	Taper per Foot										
	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	1	$1\frac{1}{4}$
$\frac{1}{2}$	.0002	.0002	.0003	.0007	.0010	.0013	.0016	.0020	.0026	.0033	
$\frac{1}{16}$	.0003	.0005	.0007	.0013	.0020	.0026	.0033	.0039	.0052	.0065	
$\frac{3}{32}$	.0007	.0010	.0013	.0026	.0039	.0052	.0065	.0078	.0104	.0130	
$\frac{1}{8}$	.0010	.0015	.0020	.0039	.0059	.0078	.0098	.0117	.0156	.0195	
$\frac{5}{32}$	.0013	.0020	.0026	.0052	.0078	.0104	.0130	.0156	.0208	.0260	
$\frac{3}{16}$	.0016	.0024	.0033	.0065	.0098	.0130	.0163	.0195	.0260	.0326	
$\frac{7}{32}$	.0020	.0029	.0039	.0078	.0117	.0156	.0195	.0234	.0312	.0391	
$\frac{1}{4}$	.0023	.0034	.0046	.0091	.0137	.0182	.0228	.0273	.0365	.0456	
$\frac{9}{32}$	.0026	.0039	.0052	.0104	.0156	.0208	.0260	.0312	.0417	.0521	
$\frac{5}{16}$	.0029	.0044	.0059	.0117	.0176	.0234	.0293	.0352	.0469	.0586	
$\frac{11}{32}$	.0033	.0049	.0065	.0130	.0195	.0260	.0326	.0391	.0521	.0651	
$\frac{3}{8}$	.0036	.0054	.0072	.0143	.0215	.0286	.0358	.0430	.0573	.0716	
$\frac{13}{32}$	.0039	.0059	.0078	.0156	.0234	.0312	.0391	.0469	.0625	.0781	
$\frac{7}{16}$	.0042	.0063	.0085	.0169	.0254	.0339	.0423	.0508	.0677	.0846	
$\frac{15}{32}$	.0046	.0068	.0091	.0182	.0273	.0365	.0456	.0547	.0729	.0911	
$\frac{1}{2}$	.0049	.0073	.0098	.0195	.0293	.0391	.0488	.0586	.0781	.0977	
1	.0052	.0078	.0104	.0208	.0312	.0417	.0521	.0625	.0833	.1042	
2	.0104	.0156	.0208	.0417	.0625	.0833	.1042	.125	.1667	.2083	
3	.0156	.0234	.0312	.0625	.0937	.1250	.1562	.1875	.250	.3125	
4	.0208	.0312	.0417	.0833	.125	.1667	.2083	.250	.3333	.4167	
5	.0260	.0391	.0521	.1042	.1562	.2083	.2604	.3125	.4167	.5208	
6	.0312	.0469	.0625	.125	.1875	.250	.3125	.375	.500	.625	
7	.0365	.0547	.0729	.1458	.2187	.2917	.3646	.4375	.5833	.7292	
8	.0417	.0625	.0833	.1667	.250	.3333	.4167	.500	.6667	.8333	
9	.0469	.0703	.0937	.1875	.2812	.375	.4687	.5625	.750	.9375	
10	.0521	.0781	.1042	.2083	.3125	.4167	.5208	.625	.8333	1.0417	
11	.0573	.0859	.1146	.2292	.3437	.4583	.5729	.6875	.9167	1.1458	
12	.0625	.0937	.125	.250	.375	.500	.625	.750	1.000	1.250	
13	.0677	.1016	.1354	.2708	.4062	.5417	.6771	.8125	1.0833	1.3542	
14	.0729	.1094	.1458	.2917	.4375	.5833	.7292	.875	1.1667	1.4583	
15	.0781	.1172	.1562	.3125	.4687	.625	.7812	.9375	1.250	1.5625	
16	.0833	.125	.1667	.3333	.500	.6667	.8333	1.000	1.3333	1.6667	
17	.0885	.1328	.1771	.3542	.5312	.7083	.8854	1.0625	1.4167	1.7708	
18	.0937	.1406	.1875	.3750	.5625	.750	.9375	1.125	1.500	1.875	
19	.0990	.1484	.1979	.3958	.5937	.7917	.9896	1.1875	1.5833	1.9792	
20	.1042	.1562	.2083	.4167	.625	.8333	1.0417	1.250	1.6667	2.0833	
21	.1094	.1641	.2187	.4375	.6562	.875	1.0937	1.3125	1.750	2.1875	
22	.1146	.1719	.2292	.4583	.6875	.9167	1.1458	1.375	1.8333	2.2917	
23	.1198	.1797	.2396	.4792	.7187	.9583	1.1979	1.4375	1.9167	2.3958	
24	.125	.1875	.250	.500	.750	1.000	1.250	1.500	2.000	2.500	

Tapers Per Foot in Inches and Corresponding Angles

Taper per Foot	Included Angle			Angle with Center Line			Taper per Foot	Included Angle			Angle with Center Line		
	Deg.	Min.	Sec.	Deg.	Min.	Sec.		Deg.	Min.	Sec.	Deg.	Min.	Sec.
1/64	0	4	28	0	2	14	1	4	46	18	2	23	9
1/32	0	8	58	0	4	29	1 1/16	5	21	44	2	40	52
3/64	0	13	26	0	6	43	1 1/8	5	57	48	2	58	54
1/16	0	17	54	0	8	57	1 3/16	6	33	26	3	16	43
5/64	0	22	22	0	11	11	1 1/4	6	59	4	3	29	32
3/32	0	26	52	0	13	26	1 5/16	7	44	48	3	52	24
7/64	0	31	17	0	15	38	1 3/8	8	20	26	4	10	13
1/8	0	35	48	0	17	54	1 7/16	8	56	2	4	28	1
9/64	0	40	15	0	20	7	1 1/2	9	31	36	4	45	48
5/32	0	44	44	0	22	22	1 9/16	10	7	10	5	3	35
11/64	0	49	11	0	24	35	1 5/8	10	42	42	5	21	21
3/16	0	53	44	0	26	52	1 11/16	11	18	14	5	39	7
13/64	0	58	12	0	29	6	1 3/4	11	53	36	5	56	48
7/32	1	2	34	0	31	17	1 13/16	12	28	58	6	14	29
15/64	1	7	1	0	33	30	1 7/8	13	4	24	6	32	12
1/4	1	11	36	0	35	48	1 15/16	13	39	50	6	49	55
17/64	1	16	13	0	38	6	2	14	15	0	7	7	30
9/32	1	20	30	0	40	15	2 1/16	14	50	10	7	25	5
19/64	1	24	48	0	42	24	2 1/8	15	25	24	7	42	42
5/16	1	29	30	0	44	45	2 3/16	16	0	38	8	0	19
21/64	1	33	48	0	46	54	2 1/4	16	35	40	8	17	50
11/32	1	38	22	0	49	11	2 5/16	17	10	42	8	35	21
23/64	1	42	40	0	51	20	2 3/8	17	45	40	8	52	50
3/8	1	47	24	0	53	42	2 7/16	18	20	54	9	10	27
25/64	1	52	12	0	56	6	2 1/2	18	55	28	9	27	44
13/32	1	56	24	0	58	12	2 9/16	19	30	0	9	45	0
27/64	2	0	48	1	0	24	2 5/8	20	5	2	10	2	31
7/16	2	5	18	1	2	39	2 11/16	20	39	46	10	19	53
29/64	2	9	48	1	4	54	2 3/4	21	14	2	10	37	1
15/32	2	14	16	1	7	8	2 13/16	21	48	18	10	54	9
31/64	2	18	44	1	9	22	2 7/8	22	23	22	11	11	41
1/2	2	23	10	1	11	35	2 15/16	22	57	24	11	28	12
33/64	2	27	36	1	13	48	3	23	32	12	11	46	6
17/32	2	32	4	1	16	2	3 1/16	24	6	50	12	3	25
35/64	2	36	32	1	18	16	3 1/8	24	40	42	12	20	21
9/16	2	41	4	1	20	32	3 3/16	25	15	34	12	37	57
37/64	2	45	34	1	22	47	3 1/4	25	48	48	12	54	24
19/32	2	50	2	1	25	1	3 5/16	26	23	22	13	11	41
39/64	2	54	30	1	27	15	3 3/8	26	56	46	13	28	23
5/8	2	59	42	1	29	51	3 7/16	27	30	8	13	45	4
41/64	3	4	10	1	32	5	3 1/2	28	4	2	14	2	1
21/32	3	7	56	1	33	58	3 9/16	28	37	56	14	18	58
43/64	3	12	24	1	36	12	3 5/8	29	11	34	14	35	47
11/16	3	16	54	1	38	27	3 11/16	29	45	12	14	52	36
45/64	3	21	12	1	40	36	3 3/4	30	18	26	15	9	13
23/32	3	25	50	1	42	55	3 13/16	30	52	4	15	26	2
47/64	3	30	28	1	45	14	3 7/8	31	25	2	15	42	31
3/4	3	34	44	1	47	22	3 15/16	31	58	10	15	59	5
49/64	3	39	2	1	49	31	4	32	31	12	16	15	36
25/32	3	43	44	1	51	52	4 1/16	33	4	14	16	32	7
51/64	3	48	26	1	54	13	4 1/8	33	36	40	16	48	20
13/16	3	52	38	1	56	19	4 3/16	34	9	6	17	4	33
53/64	3	57	20	1	58	40	4 1/4	34	42	30	17	21	15
27/32	4	1	36	2	0	48	4 5/16	35	15	54	17	37	57
55/64	4	5	54	2	2	57	4 3/8	35	47	32	17	53	46
7/8	4	10	32	2	5	16	4 7/16	36	20	10	18	10	5
57/64	4	14	50	2	7	25	4 1/2	36	52	12	18	26	6
29/32	4	19	34	2	9	47							
59/64	4	24	2	2	12	1							
15/16	4	28	24	2	14	12							
61/64	4	32	42	2	16	21							
31/32	4	37	20	2	18	40							
63/64	4	42	8	2	21	4							

Table for Computing Tapers

The Tabulated Quantities = Twice the Tangent of Half the Angle.

Deg.	0′	10′	20′	30′	40′	50′	60′
0	.00000	.00290	.00582	.00872	.01164	.01454	.01746
1	.01746	.02036	.02326	.02618	.02910	.03200	.03492
2	.03492	.03782	.04072	.04364	.04656	.04946	.05238
3	.05238	.05528	.05820	.06110	.06402	.06692	.06984
4	.06984	.07276	.07566	.07858	.08150	.08440	.08732
5	.08732	.09024	.09316	.09606	.09898	.10190	.10482
6	.10482	.10774	.11066	.11356	.11648	.11940	.12232
7	.12232	.12524	.12816	.13108	.13400	.13694	.13986
8	.13986	.14278	.14570	.14862	.15156	.15448	.15740
9	.15740	.16034	.16326	.16618	.16912	.17204	.17498
10	.17498	.17790	.18084	.18378	.18670	.18964	.19258
11	.19258	.19552	.19846	.20138	.20432	.20726	.21020
12	.21020	.21314	.21610	.21904	.22198	.22492	.22788
13	.22788	.23082	.23376	.23672	.23966	.24262	.24556
14	.24556	.24852	.25148	.25444	.25738	.26034	.26330
15	.26330	.26626	.26922	.27218	.27516	.27812	.28108
16	.28108	.28404	.28702	.28998	.29296	.29592	.29890
17	.29890	.30188	.30486	.30782	.31080	.31378	.31676
18	.31676	.31976	.32274	.32572	.32870	.33170	.33468
19	.33468	.33768	.34066	.34366	.34666	.34966	.35266
20	.35266	.35566	.35866	.36166	.36466	.36768	.37068
21	.37068	.37368	.37670	.37972	.38272	.38574	.38876
22	.38876	.39178	.39480	.39782	.40084	.40388	.40690
23	.40690	.40994	.41296	.41600	.41904	.42208	.42512
24	.42512	.42816	.43120	.43424	.43728	.44034	.44338
25	.44338	.44644	.44950	.45256	.45562	.45868	.46174
26	.46174	.46480	.46786	.47094	.47400	.47708	.48016
27	.48016	.48324	.48632	.48940	.49248	.49556	.49866
28	.49866	.50174	.50484	.50794	.51004	.51414	.51724
29	.51724	.52034	.52344	.52656	.52966	.53278	.53590
30	.53590	.53902	.54214	.54526	.54838	.55152	.55464
31	.55464	.55778	.56092	.56406	.56720	.57034	.57350
32	.57350	.57664	.57980	.58294	.58610	.58926	.59242
33	.59242	.59560	.59876	.60194	.60510	.60828	.61146
34	.61146	.61464	.61782	.62102	.62420	.62740	.63060
35	.63060	.63380	.63700	.64020	.64342	.64662	.64984
36	.64984	.65306	.65628	.65950	.66272	.66596	.66920
37	.66920	.67242	.67566	.67890	.68216	.68540	.68866
38	.68866	.69192	.69516	.69844	.70170	.70496	.70824
39	.70824	.71152	.71480	.71808	.72136	.72464	.72794
40	.72794	.73124	.73454	.73784	.74114	.74446	.74776
41	.74776	.75108	.75440	.75774	.76106	.76440	.76772
42	.76772	.77106	.77442	.77776	.78110	.78446	.78782
43	.78782	.79118	.79454	.79792	.80130	.80468	.80806
44	.80806	.81144	.81482	.81822	.82162	.82502	.82842
45	.82842	.83184	.83526	.83866	.84210	.84552	.84894

Table for Computing Tapers

The Tabulated Quantities = Twice the Tangent of Half the Angle.

Deg.	0′	10′	20′	30′	40′	50′	60′
46	.84894	.85238	.85582	.85926	.86272	.86616	.86962
47	.86962	.87308	.87656	.88002	.88350	.88698	.89046
48	.89046	.89394	.89744	.90094	.90444	.90794	.91146
49	.91146	.91496	.91848	.92202	.92554	.92908	.93262
50	.93262	.93616	.93970	.94326	.94682	.95038	.95396
51	.95396	.95752	.96110	.96468	.96828	.97186	.97546
52	.97546	.97906	.98268	.98630	.98990	.99354	.99716
53	.99716	1.00080	1.00444	1.00808	1.01174	1.01538	1.01906
54	1.01906	1.02272	1.02638	1.03006	1.03376	1.03744	1.04114
55	1.04114	1.04484	1.04854	1.05226	1.05596	1.05970	1.06342
56	1.06342	1.06716	1.07090	1.07464	1.07840	1.08214	1.08592
57	1.08592	1.08968	1.09346	1.09724	1.10102	1.10482	1.10862
58	1.10862	1.11242	1.11624	1.12006	1.12388	1.12770	1.13154
59	1.13154	1.13538	1.13924	1.14310	1.14696	1.15082	1.15470
60	1.15470	1.15858	1.16248	1.16636	1.17026	1.17418	1.17810
61	1.17810	1.18202	1.18594	1.18988	1.19382	1.19776	1.20172
62	1.20172	1.20568	1.20966	1.21362	1.21762	1.22160	1.22560
63	1.22560	1.22960	1.23362	1.23764	1.24166	1.24570	1.24974
64	1.24974	1.25378	1.25784	1.26190	1.26598	1.27006	1.27414
65	1.27414	1.27824	1.28234	1.28644	1.29056	1.29468	1.29882
66	1.29882	1.30296	1.30710	1.31126	1.31542	1.31960	1.32378
67	1.32378	1.32796	1.33216	1.33636	1.34056	1.34478	1.34902
68	1.34902	1.35326	1.35750	1.36176	1.36602	1.37028	1.37456
69	1.37456	1.37984	1.38314	1.38744	1.39176	1.39608	1.40042
70	1.40042	1.40476	1.40910	1.41346	1.41782	1.42220	1.42658
71	1.42658	1.43098	1.43538	1.43980	1.44422	1.44864	1.45308
72	1.45308	1.45754	1.46200	1.46646	1.47094	1.47542	1.47992
73	1.47992	1.48442	1.48894	1.49348	1.49800	1.50256	1.50710
74	1.50710	1.51168	1.51624	1.52084	1.52544	1.53004	1.53466
75	1.53466	1.53928	1.54392	1.54856	1.55322	1.55790	1.56258
76	1.56258	1.56726	1.57196	1.57668	1.58140	1.58612	1.59088
77	1.59088	1.59562	1.60040	1.60516	1.60996	1.61476	1.61966
78	1.61956	1.62440	1.62922	1.63406	1.63892	1.64380	1.64868
79	1.64868	1.65356	1.65846	1.66338	1.66830	1.67324	1.67820
80	1.67820	1.68316	1.68814	1.69312	1.69812	1.70314	1.70816
81	1.70816	1.71320	1.71824	1.72332	1.72836	1.73348	1.73858
82	1.73858	1.74368	1.74882	1.75396	1.75910	1.76428	1.76946
83	1.76946	1.77464	1.77984	1.78506	1.79030	1.79554	1.80080
84	1.80080	1.80608	1.81138	1.81668	1.82198	1.82732	1.83266
85	1.83266	1.83802	1.84340	1.84878	1.85418	1.85960	1.86504
86	1.86504	1.87048	1.87594	1.88142	1.88690	1.89240	1.89792
87	1.89792	1.90346	1.90902	1.91458	1.92016	1.92576	1.93138
88	1.93138	1.93700	1.94266	1.94832	1.95400	1.95968	1.96540
89	1.96540	1.97112	1.97686	1.98262	1.98840	1.99420	2.00000
90	2.						

Refer to page 583 for explanation of table.

TABLE FOR USE IN COMPUTING TAPERS

In the table on pages 581 and 582 the quantities when expressed in inches represent the taper per inch corresponding to various angles advancing by 10 minutes from 10 minutes to 90 degrees. If an angle is given as, say, $27\frac{1}{2}$ degrees and it is desired to find the corresponding taper in inches, the amount, 0.4894, may be taken directly from the table. This is the taper per inch of length measured as in Fig. 6, along the axis. The taper in inches per foot of length is found by multiplying the tabulated quantity by 12, and

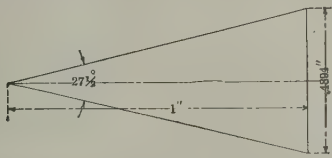


Fig. 6.—Taper per Inch and Corresponding Angle

in this particular case would be $0.4894'' \times 12 = 5.8728''$. Where the included angle is not found directly in the table, the taper per inch is found as follows: Assume that the angle in question is $12\frac{1}{4}$ degrees, then the nearest angles in the table are 12° 10′ and 12° 20′, the respective quantities tabulated under these angles being 0.21314 and 0.21610. The difference between the two is 0.00296, and as $12\frac{1}{4}$° is half-way between 12° 10′ and 12° 20′ one-half of 0.00296, or 0.00148 is added to 0.21314, giving $0.21462''$ as the taper of a piece 1 inch in length and of an included angle of $12\frac{1}{4}$ degrees. The taper per foot equals $0.21462'' \times 12 = 2.5744''$.

TABLE FOR DIMENSIONING DOVETAIL SLIDES AND GIBS

The table on page 584 is figured for machine-tool work so as to enable one to tell at a glance the amount to be added or subtracted in dimensioning dovetail slides and their gibs for the usual angles up to 60 degrees. The column for 45-degree dovetails is omitted, as A and B would, of course, be alike for this angle.

In the application of the table, assuming a base with even dimensions, as in the sketch Fig. 7, to obtain the dimensions x and y of the slide Fig. 8, allowing for the gib which may be assumed to be $\frac{1}{4}$ inch thick, the perpendicular depth of the dovetail being $\frac{5}{8}$ inch, and the angle 60 degrees, look under column A for $\frac{5}{8}$ inch and it will be found opposite this that B is 0.360 inch, which subtracted from 2 inches gives 1.640 inches, the dimension x. To find y first get the dimension 1.640 inches, then under the column for 60-degree gibs (where C is $\frac{1}{4}$ inch), D is found to be 0.289 inch, which is added to 1.640, giving 1.929 inches.

In practice this dimension is usually made a little larger, say to the nearest 64th, to allow for fitting the gib.

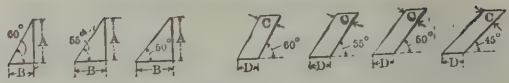


TABLE FOR DIMENSIONING DOVETAIL SLIDES AND GIBS

A	B	B	B	C	D	D	D	D
$\frac{1}{8}''$	.018″	.022″	.027″	$\frac{1}{8}''$	.144″	.152″	.163″	.176″
$\frac{1}{16}''$	.036″	.044″	.053″	$\frac{3}{16}''$	.216″	.228″	.244″	.264″
$\frac{1}{8}''$	.072″	.087″	.105″	$\frac{1}{4}''$	.289″	.305″	.326″	.353″
$\frac{1}{4}''$	.144″	.175″	.210″	$\frac{5}{16}''$	.361″	.381″	.407″	.442″
$\frac{3}{8}''$	.216″	.262″	.314″	$\frac{3}{8}''$	.433″	.457″	.489″	.530″
$\frac{1}{2}''$	.288″	.350″	.420″	$\frac{1}{2}''$	.577″	.610″	.652″	.707″
$\frac{5}{8}''$	.360″	.437″	.525″	$\frac{5}{8}''$	.721″	.762″	.815″	.883″
$\frac{3}{4}''$	.433″	.525″	.629″	$\frac{3}{4}''$	.866″	.915″	.979″	1.060″
$\frac{7}{8}''$	.505″	.612″	.734″	$\frac{7}{8}''$	1.010″	1.067″	1.142″	1.237″
1″	.577″	.700″	.839″	1″	1.154″	1.220″	1.305″	1.414″
$1\frac{1}{8}''$	.649″	.787″	.944″					
$1\frac{1}{4}''$	.721″	.875″	1.049″					
$1\frac{3}{8}''$	.794″	.962″	1.153″					
$1\frac{1}{2}''$	.866″	1.050″	1.259″					
$1\frac{3}{4}''$	1.010″	1.225″	1.469″					
2″	1.154″	1.400″	1.677″					
$2\frac{1}{4}''$	1.298″	1.575″	1.888″					
$2\frac{1}{2}''$	1.442″	1.750″	2.097″					
$2\frac{3}{4}''$	1.588″	1.925″	2.307″					
3″	1.732″	2.100″	2.517″					
$3\frac{1}{2}''$	2.020″	2.450″	2.937″					
4″	2.308″	2.800″	3.356″					
$4\frac{1}{2}''$	2.598″	3.150″	3.776″					
5″	2.885″	3.501″	4.195″					

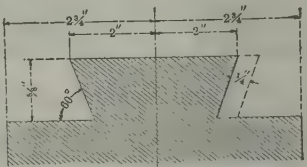


FIG. 7

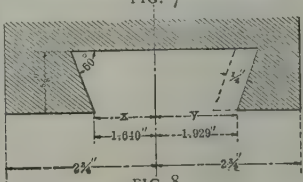


FIG. 8

MEASURING EXTERNAL AND INTERNAL DOVETAILS

The accompanying table of constants is for use with the plug method of sizing dovetail gages, etc. The constants are calculated for the plugs and angles most in use; and to use them a knowledge of arithmetic is all that is required. The formulas by which they were obtained are added for the convenience of those who may have an unusual angle to make.

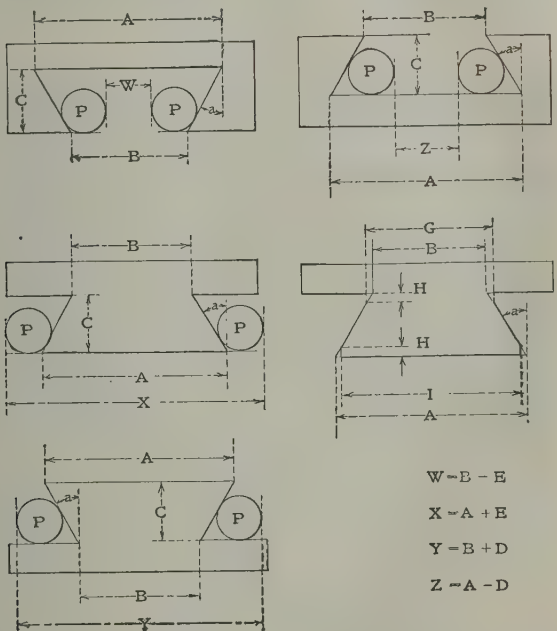


FIG. 9.—External and Internal Dovetails

As an example of the use of the table, suppose that Z, Fig. 9, is the dimension wanted, and that the dimension A and the angle a are known. A glance at the formulas above shows that $Z = A - D$. Then the constant D corresponding to the size of plug and the angle used is subtracted from A and the remainder equals Z. For instance, if $A = 4''$, the plug used $= \frac{3}{8}''$, and the angle $= 30$ degrees, then $Z = A - D = 4'' - 1.0245'' = 2.9755''$.

If A is not known but B and C are given, according to the formula below the table $A = B + C\,F$. Then if $B = 3.134''$, $C = \frac{3}{4}''$, and the angle is 30 degrees, as before, $A = B + C\,F = 3.134'' + (.75'' \times 1.1547) = 4''$, whence Z can be found, as already shown.

If the corners of the dovetail are flat, as shown in Fig. 9 at I and G, and the dimensions I and H and the angles are known, it will be found from the formulas below the table that A also $= I + H\,F$; so that if $I = 3.8557''$, $H = \frac{1}{8}''$, and the angle = 30 degrees, then $A = I + H\,F = 3.8557'' + (.125'' \times 1.1547) = 4''$, from which Z is found as before.

CONSTANTS FOR DOVETAILS

Plug		60°	55°	50°	45°	40°	35°	30°
$\frac{1}{4}''$	D	1.1830	1.0429	.9368	.8535	.7861	.7302	.6830
	E	.3170	.3288	.3410	.3536	.3666	.3802	.3943
$\frac{3}{8}''$	D	1.7745	1.5643	1.4053	1.2803	1.1792	1.0954	1.0245
	E	.4755	.4932	.5115	.5303	.5499	.5702	.5915
$\frac{1}{2}''$	D	2.3660	2.0858	1.8730	1.7070	1.5722	1.4604	1.3660
	E	.6340	.6576	.6820	.7072	.7332	.7603	.7886
$\frac{3}{4}''$	D	3.5490	3.1286	2.8106	2.5606	2.3584	2.1903	2.0490
	E	.9510	.9864	1.0230	1.0606	1.0998	1.1404	1.1830
	F	3.4641	2.8563	2.3836	2	1.6782	1.4004	1.1547

$$A = B + CF = I + HF$$
$$B = A - CF = G - HF$$
$$E = P\left(\cot.\frac{90 + a}{2}\right) + P$$
$$D = P\left(\cot.\frac{90 - a}{2}\right) + P$$
$$F = 2 \tan a$$

TOOL FOR LAYING OUT ANGLES ACCURATELY

THE bevel gage shown here is for laying out angles accurately. In using this gage set a vernier caliper or large "micrometer" to twice the sine of half the angle desired, multiplied by ten; add one-

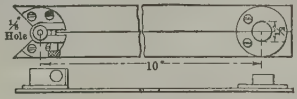


FIG. 1.—Bevel Gage for Laying Out

half inch and open the gage till it fits the vernier; this gives the angle within the limits of the measuring tool and the radius of the gage. The $\frac{1}{8}$-inch hole in the center is for a setting plug when it is desirable to lay out an angle from a given center.

The table gives the measurements over the half disks required for setting the arms of the gage to give any angle from 1 to 45 degrees, and also the setting for any number of holes in a circle from 3 to 22.

TABLE FOR SETTING TOOL FOR LAYING OUT ANGLES

GAGE SETTING FOR EVEN DEGREES

Angle Degrees	Measurement Over Disks	Angle Degrees	Measurement Over Disks	Angle Degrees	Measurement Over Disks	Angle Degrees	Measurement Over Disks
1	0.6746	12	2.5906	23	4.4874	34	6.3474
2	0.8490	13	2.764	24	4.6582	35	6.5142
3	1.0236	14	2.9374	25	4.8288	36	6.6804
4	1.1980	15	3.1106	26	4.9980	37	6.846
5	1.3724	16	3.2834	27	5.1690	38	7.0114
6	1.5468	17	3.4562	28	5.3384	39	7.1762
7	1.7210	18	3.6286	29	5.5176	40	7.3404
8	1.8952	19	3.8010	30	5.6764	41	7.5042
9	2.0692	20	3.9730	31	5.8448	42	7.6674
10	2.2432	21	4.1448	32	6.0128	43	7.830
11	2.4170	22	4.3162	33	6.1804	44	7.9922
						45	8.1536

GAGE SETTINGS FOR HOLES IN A CIRCLE

No. of Holes in Circle	Measurement Over Disks	No. of Holes in Circle	Measurement Over Disks	No. of Holes in Circle	Measurement Over Disks	No. of Holes in Circle	Measurement Over Disks
3	17.8206	8	8.1536	13	5.2864	18	3.9730
4	14.6422	9	7.3404	14	4.9504	19	3.7918
5	12.2558	10	6.6802	15	4.6582	20	3.6286
6	10.5	11	6.1346	16	4.4018	21	3.4808
7	9.1776	12	5.6762	17	4.1750	22	3.3462

THE SINE BAR

The sine bar is an instrument of precision used by the toolmaker in laying out, setting, testing and otherwise dealing with angular work which requires a close degree of accuracy in its dimensions. It consists of a bar of steel with two disks of equal diameter secured near the ends of the bar and having their centers on a line exactly parallel with the edge of the sine bar. The bar itself may be either tool steel hardened and ground or machine steel case hardened.

An improved form of sine bar is shown in Fig. 1. There are various other designs, all having for their object a convenient means of locating work at the desired angle upon an angle plate or other

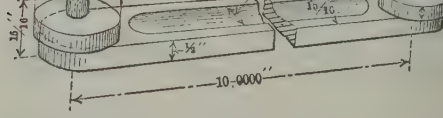


FIG. 2

plate so that the work may be set at once to the desired angle for laying out, drilling or machining otherwise. It is customary to locate the disks on the sine bar at a center distance of either 5 or 10 inches, these being convenient lengths and, moreover, forming handy figures for multiplying the quantities for the corresponding angles as taken from a table of sines, in setting the sine bar in position.

The disks are used for setting the bar at the correct angle by measuring up under the disks with a vernier height gage, the bar then being clamped securely to the angle plate. With the sine bar in Fig. 2, the disks are large enough to project over the edges of the bar so that the lower disk always rests directly upon the surface plate or upon a parallel on the plate, and the sine bar may be set very easily as it is merely swung upon its lower disk until the upper disk is at the right height as determined by the height gage.

Use of the Special Table

It is a convenience in using the sine bar to have a special table computed to cover degrees and minutes with sines calculated for a radius of 10; that is, the quantities are ten times the sines as taken from a regular table of sines. Thus, in the accompanying table the constants are figured for direct setting of the 10-inch sine bar. If a 5-inch bar is used these constants should be divided by two.

Suppose, in Fig. 3, it is desired to set the bar at an angle of 25 degrees, as indicated in the sketch, Fig. 4. In the triangle, Fig. 3, the radius, 10 inches, is the center distance between the sine bar disks, and the dimension required to be found is the height *H*. Referring to our table herewith, we find opposite the angle 25 degrees, the constant 4.2262, so that the height of the center of the upper disk must be 4.2262 inches above the lower disk. In Fig. 4

the sine bar is shown set with the lower disk center 1 inch above the surface plate as a matter of convenience so that the other disk must be set 4.2262 inches plus 1 inch or a center height of 5.2226 inches. With the form of sine bar in Fig. 4, where the lower disk rests directly upon a surface plate, the setting for the upper disk would be 4.2262 plus ½ inch or 4.7262 inches.

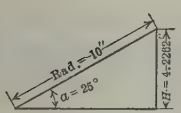


FIG. 3

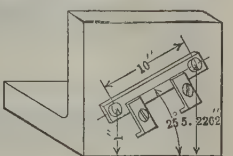


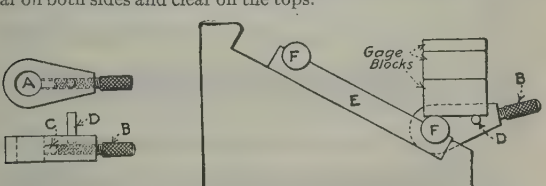
FIG. 4

Attachment for Use with the Sine Bar

The attachment illustrated in Fig. 5 was developed to be used with Johansson blocks in connection with the sine bar for more accurate setting or testing of angles than is usually obtained with the height gage. It is shown in use in measuring the angle on the shoe for an angular jig.

The body of the attachment is made of machine steel. The large hole *A* is a slip fit for the plug of the sine bar. The knurled head screw *B* and the brass button *C* provide means for clamping. The small pin *D* driven into the machine-steel body on which one end of the gage blocks rests when in use completes the attachment.

In Fig. 6, the sine bar *E* has the plugs *F* extending beyond the bar on both sides and clear on the tops.



FIGS. 5 and 6.—Attachment for Use with the Sine Bar

In use, the attachment is slipped over one of the plugs with the pin *D* pointed in. The sine bar is clamped on to the piece to be tested, and the required combination of blocks placed so as to rest on top of the plug of the sine bar and the pin of the attachment; with the aid of an indicator the blocks are then set parallel with the surface plate, adjustment being made by tapping the attachment up or down as required.

After the blocks are set parallel, all that is necessary is to run the indicator over the higher plug of the sine bar and the top surface of blocks to determine the accuracy of the setting.

Sine Bar Table

Min.	Constant, 0 Deg.	Constant, 1 Deg.	Constant, 2 Deg.	Constant, 3 Deg.	Constant, 4 Deg.	Constant, 5 Deg.	Constant, 6 Deg.	Constant, 7 Deg.	Constant, 8 Deg.
0	.0000	.1745	.3490	.5234	.6976	.8716	1.0453	1.2187	1.3917
1	.0029	.1774	.3519	.5263	.7005	.8745	1.0482	1.2216	1.3946
2	.0058	.1803	.3548	.5292	.7034	.8774	1.0511	1.2245	1.3975
3	.0087	.1832	.3577	.5321	.7063	.8803	1.0540	1.2274	1.4004
4	.0116	.1862	.3606	.5350	.7092	.8831	1.0569	1.2302	1.4033
5	.0145	.1891	.3635	.5379	.7121	.8860	1.0597	1.2331	1.4061
6	.0175	.1920	.3664	.5408	.7150	.8889	1.0626	1.2360	1.4090
7	.0204	.1949	.3693	.5437	.7179	.8918	1.0655	1.2389	1.4119
8	.0233	.1978	.3723	.5466	.7208	.8947	1.0684	1.2418	1.4148
9	.0262	.2007	.3752	.5495	.7237	.8976	1.0713	1.2447	1.4177
10	.0291	.2036	.3781	.5524	.7266	.9005	1.0742	1.2476	1.4205
11	.0320	.2065	.3810	.5553	.7295	.9034	1.0771	1.2504	1.4234
12	.0349	.2094	.3839	.5582	.7324	.9063	1.0800	1.2533	1.4263
13	.0378	.2123	.3868	.5611	.7353	.9092	1.0829	1.2562	1.4292
14	.0407	.2132	.3897	.5640	.7382	.9121	1.0858	1.2591	1.4320
15	.0436	.2181	.3926	.5669	.7411	.9150	1.0887	1.2620	1.4349
16	.0465	.2211	.3955	.5698	.7440	.9179	1.0916	1.2649	1.4378
17	.0495	.2240	.3984	.5727	.7469	.9208	1.0945	1.2678	1.4407
18	.0524	.2269	.4013	.5756	.7498	.9237	1.0973	1.2706	1.4436
19	.0553	.2298	.4042	.5785	.7527	.9266	1.1002	1.2735	1.4464
20	.0582	.2327	.4071	.5814	.7556	.9295	1.1031	1.2764	1.4493
21	.0611	.2356	.4100	.5844	.7585	.9324	1.1060	1.2793	1.4522
22	.0640	.2385	.4129	.5873	.7614	.9353	1.1089	1.2822	1.4551
23	.0669	.2414	.4159	.5902	.7643	.9382	1.1118	1.2851	1.4580
24	.0698	.2443	.4188	.5931	.7672	.9411	1.1147	1.2880	1.4608
25	.0727	.2472	.4217	.5960	.7701	.9440	1.1176	1.2908	1.4637
26	.0756	.2501	.4246	.5989	.7730	.9469	1.1205	1.2937	1.4666
27	.0785	.2530	.4275	.6018	.7739	.9498	1.1234	1.2966	1.4695
28	.0814	.2560	.4304	.6047	.7788	.9527	1.1269	1.2995	1.4723
29	.0844	.2589	.4333	.6076	.7817	.9556	1.1291	1.3024	1.4752
30	.0873	.2618	.4362	.6105	.7846	.9585	1.1320	1.3053	1.4781

31	.0902	.2647	.4391	.6134	.7875	.9614	1.1349	1.3081	1.4810
32	.0931	.2676	.4420	.6163	.7904	.9642	1.1378	1.3110	1.4838
33	.0960	.2705	.4449	.6192	.7933	.9671	1.1407	1.3139	1.4867
34	.0989	2734	.4478	.6221	.7962	.9700	1.1436	1.3168	1.4896
35	.1018	.2763	.4507	.6250	.7993	.9729	1.1465	1.3197	1.4925
36	.1047	.2792	.4536	.6279	.8020	.9758	1.1494	1.3226	1.4954
37	.1076	.2821	.4565	.6308	.8049	.9787	1.1523	1.3254	1.4982
38	.1105	.2850	.4594	.6337	.8078	.9816	1.1552	1.3283	1.5011
39	.1134	.2879	.4623	.6360	.8107	.9845	1.1580	1.3312	1.5040
40	.1164	.2908	.4653	.6395	.8136	.9874	1.1609	1.3341	1.5069
41	.1193	.2938	.4682	.6424	.8165	.9903	1.1638	1.3370	1.5097
42	.1222	.2967	.4711	.6453	.8194	.9932	1.1667	1.3399	1.5126
43	.1251	.2996	.4740	.6482	.8223	.9961	1.1696	1.3427	1.5155
44	.1280	.3025	.4769	.6511	.8252	.9990	1.1725	1.3456	1.5184
45	.1309	.3054	.4798	.6540	.8281	1.0019	1.1754	1.3485	1.5212
46	.1338	.3083	.4827	.6569	.8310	1.0048	1.1783	1.3514	1.5241
47	.1367	.3112	.4856	.6598	.8339	1.0077	1.1812	1.3543	1.5270
48	.1396	.3141	.4885	.6627	.8368	1.0106	1.1840	1.3572	1.5299
49	.1425	.3170	.4914	.6656	.8397	1.0135	1.1869	1.3600	1.5327
50	.1454	.3199	.4943	.6685	.8426	1.0164	1.1898	1.3629	1.5356
51	.1483	.3228	.4972	.6714	.8455	1.0192	1.1927	1.3658	1.5385
52	.1513	.3257	.5001	.6743	.8484	1.0221	1.1956	1.3687	1.5414
53	.1542	.3286	.5030	.6773	.8513	1.0250	1.1985	1.3716	1.5442
54	.1571	.3316	.5059	.6802	.8542	1.0279	1.2014	1.3744	1.5471
55	.1600	.3345	.5088	.6831	.8571	1.0308	1.2043	1.3773	1.5500
56	.1629	.3374	.5117	.6860	.8600	1.0337	1.2071	1.3802	1.5529
57	.1658	.3403	.5146	.6889	.8629	1.0366	1.2100	1.3831	1.5557
58	.1687	.3432	.5175	.6918	.8658	1.0395	1.2129	1.3860	1.5586
59	.1716	.3461	.5205	.6947	.8687	1.0424	1.2158	1.3889	1.5615
60	.1745	.3490	.5234	.6976	.8716	1.0453	1.2187	1.3917	1.5643

SINE BAR TABLE—*Continued*

Min.	Constant, 9 Deg.	Constant, 10 Deg.	Constant, 11 Deg.	Constant, 12 Deg.	Constant, 13 Deg.	Constant, 14 Deg.	Constant, 15 Deg.	Constant, 16 Deg.	Constant, 17 Deg.
0	1.5643	1.7365	1.9081	2.0791	2.2495	2.4192	2.5882	2.7564	2.9237
1	1.5672	1.7393	1.9109	2.0820	2.2523	2.4220	2.5910	2.7592	2.9265
2	1.5701	1.7422	1.9138	2.0848	2.2552	2.4249	2.5938	2.7620	2.9293
3	1.5730	1.7451	1.9167	2.0877	2.2580	2.4277	2.5966	2.7648	2.9321
4	1.5758	1.7479	1.9195	2.0905	2.2608	2.4305	2.5994	2.7676	2.9348
5	1.5787	1.7508	1.9224	2.0933	2.2637	2.4333	2.6022	2.7704	2.9376
6	1.5816	1.7537	1.9252	2.0962	2.2665	2.4362	2.6050	2.7731	2.9404
7	1.5845	1.7565	1.9281	2.0990	2.2693	2.4390	2.6079	2.7759	2.9432
8	1.5873	1.7594	1.9309	2.1019	2.2722	2.4418	2.6107	2.7787	2.9460
9	1.5902	1.7623	1.9338	2.1047	2.2750	2.4446	2.6135	2.7815	2.9487
10	1.5931	1.7651	1.9366	2.1076	2.2778	2.4474	2.6163	2.7843	2.9515
11	1.5959	1.7680	1.9395	2.1104	2.2807	2.4503	2.6191	2.7871	2.9543
12	1.5988	1.7708	1.9423	2.1132	2.2835	2.4531	2.6219	2.7899	2.9571
13	1.6017	1.7737	1.9452	2.1161	2.2863	2.4559	2.6247	2.7927	2.9599
14	1.6046	1.7766	1.9481	2.1189	2.2892	2.4587	2.6275	2.7955	2.9626
15	1.6074	1.7794	1.9509	2.1218	2.2920	2.4615	2.6303	2.7983	2.9654
16	1.6100	1.7823	1.9538	2.1246	2.2948	2.4644	2.6331	2.8011	2.9682
17	1.6132	1.7852	1.9566	2.1275	2.2977	2.4672	2.6359	2.8039	2.9710
18	1.6160	1.7880	1.9595	2.1303	2.3005	2.4700	2.6387	2.8067	2.9737
19	1.6189	1.7909	1.9623	2.1331	2.3033	2.4728	2.6415	2.8095	2.9765
20	1.6218	1.7937	1.9652	2.1360	2.3062	2.4756	2.6443	2.8123	2.9793
21	1.6246	1.7966	1.9680	2.1388	2.3090	2.4784	2.6471	2.8150	2.9821
22	1.6275	1.7995	1.9709	2.1417	2.3118	2.4813	2.6500	2.8178	2.9849
23	1.6304	1.8023	1.9737	2.1445	2.3146	2.4841	2.6528	2.8206	2.9876
24	1.6333	1.8052	1.9766	2.1474	2.3175	2.4869	2.6556	2.8234	2.9904
25	1.6361	1.8081	1.9794	2.1502	2.3203	2.4897	2.6584	2.8262	2.9932
26	1.6390	1.8109	1.9823	2.1530	2.3231	2.4925	2.6612	2.8290	2.9960
27	1.6419	1.8138	1.9831	2.1559	2.3260	2.4954	2.6640	2.8318	2.9987
28	1.6447	1.8166	1.9880	2.1587	2.3288	2.4982	2.6668	2.8346	3.0015
29	1.6476	1.8195	1.9908	2.1616	2.3316	2.5010	2.6696	2.8374	3.0043
30	1.6505	1.8224	1.9937	2.1644	2.3345	2.5038	2.6724	2.8402	3.0071

31	1.6533	1.8252	1.9965	2.1672	3.3373	2.5066	2.6752	2.8429	3.0098
32	1.6562	1.8281	1.9994	2.1701	2.3401	2.5094	2.6780	2.8457	3.0126
33	1.6591	1.8309	2.0022	2.1729	2.3429	2.5122	2.6808	2.8485	3.0154
34	1.6620	1.8338	2.0031	2.1758	2.3458	2.5151	2.6836	2.8513	3.0182
35	1.6648	1.8367	2.0079	2.1786	2.3486	2.5179	2.6864	2.8541	3.0209
36	1.6677	1.8395	2.0108	2.1814	2.3514	2.5207	2.6892	2.8569	3.0237
37	1.6706	1.8424	2.0136	2.1843	2.3542	2.5235	2.6920	2.8597	3.0265
38	1.6734	1.8452	2.0165	2.1871	2.3571	2.5263	2.6948	2.8625	3.0292
39	1.6763	1.8481	2.0193	2.1899	2.3599	2.5291	2.6976	2.8652	3.0320
40	1.6792	1.8509	2.0222	2.1928	2.3627	2.5320	2.7004	2.8680	3.0348
41	1.6820	1.8538	2.0250	2.1956	2.3656	2.5348	2.7032	2.8708	3.0376
42	1.6849	1.8567	2.0279	2.1985	2.3684	2.5376	2.7060	2.8736	3.0403
43	1.6878	1.8595	2.0307	2.2013	2.3712	2.5404	2.7088	2.8764	3.0431
44	1.6906	1.8624	2.0336	2.2041	2.3740	2.5432	2.7116	2.8792	3.0459
45	1.6935	1.8652	2.0364	2.2070	2.3769	2.5460	2.7144	2.8820	3.0486
46	1.6964	1.8681	2.0393	2.2098	2.3797	2.5488	2.7172	2.8847	3.0514
47	1.6992	1.8710	2.0421	2.2126	2.3825	2.5516	2.7200	2.8875	3.0542
48	1.7021	1.8738	2.0450	2.2155	2.3853	2.5545	2.7228	2.8903	3.0570
49	1.7050	1.8767	2.0478	2.2183	2.3882	2.5573	2.7256	2.8931	3.0597
50	1.7078	1.8795	2.0507	2.2212	2.3910	2.5601	2.7284	2.8959	3.0625
51	1.7107	1.8824	2.0535	2.2240	2.3938	2.5629	2.7312	2.8987	3.0653
52	1.7136	1.8852	2.0563	2.2268	2.3966	2.5657	2.7340	2.9015	3.0680
53	1.7164	1.8881	2.0592	2.2297	2.3995	2.5685	2.7368	2.9042	3.0708
54	1.7193	1.8910	2.0620	2.2325	2.4023	2.5713	2.7396	2.9070	3.0736
55	1.7222	1.8938	2.0649	2.2353	2.4051	2.5741	2.7424	2.9098	3.0763
56	1.7250	1.8967	2.0677	2.2382	2.4073	2.5769	2.7452	2.9126	3.0791
57	1.7279	1.8995	2.0706	2.2410	2.4128	2.5798	2.7480	2.9154	3.0819
58	1.7308	1.9024	2.0734	2.2438	2.4136	2.5826	2.7508	2.9182	3.0846
59	1.7336	1.9052	2.0763	2.2467	2.4164	2.5854	2.7536	2.9209	3.0874
60	1.7365	1.9081	2.0791	2.2495	2.4192	2.5882	2.7564	2.9237	3.0902

SINE BAR TABLE—*Continued*

Min.	Constant, 18 Deg.	Constant, 19 Deg.	Constant, 20 Deg.	Constant, 21 Deg.	Constant, 22 Deg.	Constant, 23 Deg.	Constant, 24 Deg.	Constant, 25 Deg.	Constant, 26 Deg.
0	3.0902	3.2557	3.4202	3.5837	3.7461	3.9073	4.0674	4.2262	4.3837
1	3.0929	3.2584	3.4229	3.5864	3.7488	3.9100	4.0700	4.2288	4.3863
2	3.0957	3.2612	3.4257	3.5891	3.7515	3.9127	4.0727	4.2315	4.3889
3	3.0986	3.2639	3.4284	3.5918	3.7542	3.9153	4.0753	4.2341	4.3916
4	3.1012	3.2667	3.4311	3.5945	3.7569	3.9180	4.0780	4.2367	4.3942
5	3.1040	3.2694	3.4339	3.5973	3.7595	3.9207	4.0806	4.2394	4.3968
6	3.1068	3.2722	3.4366	3.6000	3.7622	3.9234	4.0833	4.2420	4.3994
7	3.1095	3.2749	3.4393	3.6027	3.7649	3.9260	4.0860	4.2446	4.4020
8	3.1123	3.2777	3.4421	3.6054	3.7676	3.9287	4.0886	4.2473	4.4046
9	3.1151	3.2804	3.4448	3.6081	3.7703	3.9314	4.0913	4.2499	4.4072
10	3.1178	3.2832	3.4475	3.6108	3.7730	3.9341	4.0939	4.2525	4.4098
11	3.1206	3.2859	3.4503	3.6135	3.7757	3.9367	4.0966	4.2552	4.4124
12	3.1233	3.2887	3.4530	3.6162	3.7784	3.9394	4.0992	4.2578	4.4151
13	3.1261	3.2914	3.4557	3.6190	3.7811	3.9421	4.1019	4.2604	4.4177
14	3.1289	3.2942	3.4584	3.6217	3.7838	3.9448	4.1045	4.2631	4.4203
15	3.1316	3.2969	3.4612	3.6244	3.7865	3.9474	4.1072	4.2657	4.4229
16	3.1344	3.2997	3.4639	3.6271	3.7892	3.9501	4.1098	4.2683	4.4255
17	3.1372	3.3024	3.4666	3.6298	3.7919	3.9528	4.1125	4.2709	4.4281
18	3.1399	3.3051	3.4694	3.6325	3.7946	3.9555	4.1151	4.2736	4.4307
19	3.1427	3.3079	3.4721	3.6352	3.7973	3.9581	4.1178	4.2762	4.4333
20	3.1454	3.3106	3.4748	3.6379	3.7999	3.9608	4.1204	4.2788	4.4359
21	3.1482	3.3134	3.4775	3.6406	3.8026	3.9635	4.1231	4.2815	4.4385
22	3.1510	3.3161	3.4803	3.6434	3.8053	3.9661	4.1257	4.2841	4.4411
23	3.1537	3.3189	3.4830	3.6461	3.8080	3.9688	4.1284	4.2867	4.4437
24	3.1565	3.3216	3.4857	3.6488	3.8107	3.9715	4.1310	4.2894	4.4464
25	3.1593	3.3244	3.4884	3.6515	3.8134	3.9741	4.1337	4.2920	4.4490
26	3.1620	3.3271	3.4912	3.6542	3.8161	3.9768	4.1363	4.2946	4.4516
27	3.1648	3.3298	3.4939	3.6569	3.8188	3.9795	4.1390	4.2972	4.4542
28	3.1675	3.3326	3.4966	3.6586	3.8215	3.9822	4.1416	4.2999	4.4568
29	3.1703	3.3353	3.4993	3.6623	3.8241	3.9848	4.1443	4.3025	4.4594
30	3.1730	3.3381	3.5021	3.6650	3.8268	3.9875	4.1469	4.3051	4.4620

31	3.1758	3.3408	3.5048	3.6677	3.8295	3.9902	4.1496	4.3077	4.4646
32	3.1786	3.3436	3.5075	3.6704	3.8322	3.9928	4.1522	4.3104	4.4672
33	3.1813	3.3463	3.5102	3.6731	3.8349	3.9955	4.1549	4.3130	4.4698
34	3.1841	3.3490	3.5130	3.6758	3.8376	3.9982	4.1575	4.3156	4.4724
35	3.1868	3.3518	3.5157	3.6785	3.8403	4.0008	4.1602	4.3182	4.4750
36	3.1896	3.3545	3.5184	3.6812	3.8430	4.0035	4.1628	4.3209	4.4776
37	3.1923	3.3573	3.5211	3.6839	3.8456	4.0062	4.1655	4.3235	4.4802
38	3.1951	3.3600	3.5239	3.6867	3.8483	4.0088	4.1681	4.3261	4.4828
39	3.1979	3.3627	3.5266	3.6894	3.8510	4.0115	4.1707	4.3287	4.4854
40	3.2006	3.3655	3.5293	3.6921	3.8537	4.0141	4.1734	4.3313	4.4880
41	3.2034	3.3682	3.5320	3.6948	3.8564	4.0168	4.1760	4.3340	4.4906
42	3.2061	3.3710	3.5347	3.6975	3.8591	4.0195	4.1787	4.3366	4.4932
43	3.2089	3.3737	3.5375	3.7002	3.8617	4.0221	4.1813	4.3392	4.4958
44	3.2116	3.3764	3.5402	3.7029	3.8644	4.0248	4.1840	4.3418	4.4984
45	3.2144	3.3792	3.5429	3.7056	3.8671	4.0275	4.1866	4.3445	4.5010
46	3.2171	3.3819	3.5456	3.7083	3.8698	4.0301	4.1892	4.3471	4.5036
47	3.2199	3.3846	3.5484	3.7110	3.8725	4.0328	4.1919	4.3497	4.5062
48	3.2227	3.3874	3.5511	3.7137	3.8752	4.0355	4.1945	4.3523	4.5088
49	3.2254	3.3901	3.5538	3.7164	3.8778	4.0381	4.1972	4.3549	4.5114
50	3.2282	3.3929	3.5565	3.7191	3.8805	4.0408	4.1998	4.3575	4.5140
51	3.2309	3.3956	3.5592	3.7218	3.8832	4.0434	4.2024	4.3602	4.5166
52	3.2337	3.3983	3.5619	3.7245	3.8859	4.0461	4.2051	4.3628	4.5192
53	3.2364	3.4011	3.5647	3.7272	3.8886	4.0488	4.2077	4.3654	4.5218
54	3.2392	3.4038	3.5674	3.7299	3.8912	4.0514	4.2104	4.3680	4.5243
55	3.2419	3.4065	3.5701	3.7326	3.8939	4.0541	4.2130	4.3706	4.5269
56	3.2447	3.4093	3.5728	3.7353	3.8966	4.0567	4.2156	4.3733	4.5295
57	3.2474	3.4120	3.5755	3.7380	3.8993	4.0594	4.2183	4.3759	4.5321
58	3.2502	3.4147	3.5782	3.7407	3.9020	4.0621	4.2209	4.3785	4.5347
59	3.2529	3.4175	3.5810	3.7434	3.9046	4.0647	4.2235	4.3811	4.5373
60	3.2557	3.4202	3.5837	3.7461	3.9073	4.0674	4.2262	4.3837	4.5399

SINE BAR TABLE—*Continued*

Min.	Constant, 27 Deg.	Constant, 28 Deg.	Constant, 29 Deg.	Constant, 30 Deg.	Constant, 31 Deg.	Constant, 32 Deg.	Constant, 33 Deg.	Constant, 34 Deg.	Constant, 35 Deg.
0	4.5399	4.6947	4.8481	5.0000	5.1504	5.2992	5.4464	5.5919	5.7358
1	4.5425	4.6973	4.8506	5.0025	5.1529	5.3017	5.4488	5.5943	5.7381
2	4.5451	4.6999	4.8532	5.0050	5.1554	5.3041	5.4513	5.5968	5.7405
3	4.5477	4.7024	4.8557	5.0076	5.1579	5.3066	5.4537	5.5992	5.7429
4	4.5503	4.7050	4.8583	5.0101	5.1604	5.3091	5.4561	5.6016	5.7453
5	4.5529	4.7076	4.8608	5.0126	5.1628	5.3115	5.4586	5.6040	5.7477
6	4.5554	4.7101	4.8634	5.0151	5.1653	5.3140	5.4610	5.6064	5.7501
7	4.5580	4.7127	4.8659	5.0176	5.1678	5.3164	5.4635	5.6088	5.7524
8	4.5606	4.7153	4.8684	5.0201	5.1703	5.3189	5.4659	5.6112	5.7548
9	4.5632	4.7178	4.8710	5.0227	5.1728	5.3214	5.4683	5.6136	5.7572
10	4.5658	4.7204	4.8730	5.0252	5.1753	5.3238	5.4708	5.6160	5.7596
11	4.5684	4.7229	4.8761	5.0277	5.1778	5.3263	5.4732	5.6184	5.7619
12	4.5710	4.7255	4.8786	5.0302	5.1803	5.3288	5.4756	5.6208	5.7643
13	4.5736	4.7281	4.8811	5.0327	5.1828	5.3312	5.4781	5.6232	5.7667
14	4.5762	4.7306	4.8837	5.0352	5.1852	5.3337	5.4805	5.6256	5.7691
15	4.5787	4.7332	4.8852	5.0377	5.1877	5.3361	5.4829	5.6280	5.8715
16	4.5813	4.7358	4.8888	5.0403	5.1902	5.3386	5.4854	5.6305	5.7738
17	4.5839	4.7383	4.8913	5.0428	5.1927	5.3411	5.4878	5.6329	5.7762
18	4.5865	4.7409	4.8938	5.0453	5.1952	5.3435	5.4902	5.6353	5.7786
19	4.5891	4.7434	4.8964	5.0478	5.1977	5.3460	5.4927	5.6377	5.7810
20	4.5917	4.7460	4.8989	5.0503	5.2002	5.3484	5.4951	5.6401	5.7833
21	4.5942	4.7486	4.9014	5.0528	5.2096	5.3509	5.4975	5.6425	5.7857
22	4.5968	4.7511	4.9040	5.0553	5.2051	5.3534	5.4999	5.6449	5.7881
23	4.5994	4.7537	4.9065	5.0578	5.2076	5.3558	5.5024	5.6473	5.7904
24	4.6020	4.7562	4.9090	5.0603	5.2101	5.3583	5.5048	5.6497	5.7928
25	4.6046	4.7588	4.9116	5.0628	5.2126	5.3607	5.5072	5.6521	5.7952
26	4.6072	4.7614	4.9141	5.0654	5.2151	5.3632	5.5097	5.6545	5.7976
27	4.6097	4.7639	4.9166	5.0679	5.2175	5.3656	5.5121	5.6569	5.7999
28	4.6123	4.7665	4.9192	5.0704	5.2200	5.3681	5.5145	5.6593	5.8023
29	4.6149	4.7690	4.9217	5.0729	5.2225	5.3705	5.5169	5.6617	5.8047
30	4.6175	4.7716	4.9242	5.0754	5.2250	5.3730	5.5194	5.6641	5.8070

31	4.6201	4.7741	4.9268	5.0779	5.2275	5.3754	5.5218	5.6665	5.8094
32	4.6246	4.7787	4.9313	5.0824	5.2319	5.3798	5.5262	5.6709	5.8138
33	4.6292	4.7833	4.9358	5.0869	5.2364	5.3843	5.5306	5.6753	5.8181
34	4.6338	4.7878	4.9403	5.0914	5.2408	5.3887	5.5350	5.6797	5.8225
35	4.6384	4.7924	4.9448	5.0959	5.2453	5.3932	5.5394	5.6841	5.8268
36	4.6430	4.7969	4.9494	5.1004	5.2498	5.3976	5.5438	5.6885	5.8312
37	4.6475	4.8015	4.9539	5.1049	5.2542	5.4021	5.5482	5.6929	5.8355
38	4.6521	4.8060	4.9584	5.1094	5.2587	5.4065	5.5526	5.6973	5.8399
39	4.6567	4.8106	4.9630	5.1139	5.2632	5.4110	5.5570	5.7017	5.8442
40	4.6613	4.8151	4.9675	5.1184	5.2676	5.4154	5.5614	5.7061	5.8486
41	4.6658	4.8197	4.9721	5.1229	5.2721	5.4199	5.5658	5.7105	5.8529
42	4.6704	4.8242	4.9766	5.1274	5.2765	5.4243	5.5702	5.7149	5.8573
43	4.6750	4.8288	4.9812	5.1319	5.2810	5.4288	5.5746	5.7193	5.8616
44	4.6796	4.8333	4.9857	5.1364	5.2854	5.4332	5.5790	5.7237	5.8660
45	4.6841	4.8379	4.9902	5.1409	5.2899	5.4377	5.5834	5.7281	5.8703
46	4.6887	4.8424	4.9948	5.1454	5.2943	5.4421	5.5878	5.7325	5.8747
47	4.6933	4.8470	4.9993	5.1499	5.2988	5.4465	5.5922	5.7369	5.8790
48	4.6979	4.8515	5.0039	5.1544	5.3032	5.4510	5.5966	5.7413	5.8834
49	4.7024	4.8561	5.0084	5.1589	5.3077	5.4554	5.6010	5.7457	5.8877
50	4.7070	4.8606	5.0130	5.1634	5.3121	5.4598	5.6054	5.7501	5.8921
51	4.7116	4.8652	5.0175	5.1679	5.3166	5.4643	5.6098	5.7545	5.8964
52	4.7162	4.8697	5.0220	5.1724	5.3210	5.4687	5.6142	5.7589	5.9008
53	4.7207	4.8743	5.0266	5.1769	5.3255	5.4731	5.6186	5.7633	5.9051
54	4.7253	4.8788	5.0311	5.1814	5.3299	5.4776	5.6230	5.7677	5.9095
55	4.7299	4.8834	5.0357	5.1859	5.3344	5.4820	5.6274	5.7721	5.9138
56	4.7345	4.8879	5.0402	5.1904	5.3388	5.4864	5.6318	5.7765	5.9182
57	4.7390	4.8925	5.0447	5.1949	5.3433	5.4909	5.6362	5.7809	5.9225
58	4.7436	4.8970	5.0493	5.1994	5.3477	5.4953	5.6406	5.7853	5.9269
59	4.7482	4.9016	5.0538	5.2039	5.3522	5.4997	5.6450	5.7897	5.9312
60	4.7527	4.9061	5.0584	5.2084	5.3566	5.5042	5.6494	5.7941	5.9356
	4.7573	4.9107	5.0629	5.2129	5.3611	5.5086	5.6538	5.7985	5.9399
	4.7618	4.9152	5.0675	5.2174	5.3655	5.5130	5.6582	5.8029	5.9443
	4.7664	4.9198	5.0720	5.2219	5.3700	5.5174	5.6626	5.8073	5.9486
	4.7710	4.9243	5.0765	5.2264	5.3744	5.5218	5.6670	5.8117	5.9530
	4.7756	4.9289	5.0811	5.2309	5.3789	5.5262	5.6714	5.8161	5.9573
	4.7801	4.9334	5.0856	5.2354	5.3833	5.5306	5.6758	5.8205	5.9617
	4.7847	4.9380	5.0902	5.2399	5.3877	5.5350	5.6802	5.8249	5.9660
	4.7893	4.9425	5.0947	5.2443	5.3922	5.5394	5.6846	5.8293	5.9704
	4.7938	4.9471	5.0993	5.2488	5.3966	5.5438	5.6890	5.8337	5.9747
	4.7984	4.9516	5.1038	5.2533	5.4011	5.5482	5.6934	5.8381	5.9791
	4.8030	4.9562	5.1084	5.2577	5.4055	5.5526	5.6978	5.8425	5.9834
	4.8076	4.9607	5.1129	5.2622	5.4100	5.5570	5.7022	5.8469	5.9878
	4.8121	4.9653	5.1175	5.2667	5.4144	5.5614	5.7066	5.8513	5.9921
	4.8167	4.9698	5.1220	5.2711	5.4189	5.5658	5.7110	5.8557	5.9965
	4.8213	4.9744	5.1266	5.2756	5.4233	5.5702	5.7154	5.8601	6.0008
	4.8259	4.9789	5.1311	5.2801	5.4278	5.5746	5.7198	5.8645	6.0052
	4.8304	4.9835	5.1357	5.2845	5.4322	5.5790	5.7242	5.8689	6.0095
	4.8350	4.9880	5.1402	5.2890	5.4367	5.5834	5.7286	5.8733	6.0139
	4.8396	4.9926	5.1448	5.2935	5.4411	5.5878	5.7330	5.8777	6.0182
	4.8442	4.9971	5.1493	5.2979	5.4456	5.5922	5.7374	5.8821	6.0226
	4.8487	5.0017	5.1539	5.3024	5.4500	5.5966	5.7418	5.8865	6.0269
	4.8533	5.0062	5.1584	5.3068	5.4544	5.6010	5.7462	5.8909	6.0313
	4.8579	5.0108	5.1630	5.3113	5.4589	5.6054	5.7506	5.8953	6.0356
	4.8625	5.0153	5.1675	5.3158	5.4633	5.6098	5.7550	5.8997	6.0400
	4.8671	5.0199	5.1721	5.3203	5.4677	5.6142	5.7594	5.9041	6.0443
	4.8716	5.0244	5.1766	5.3247	5.4722	5.6186	5.7638	5.9085	6.0487
	4.8762	5.0290	5.1812	5.3292	5.4766	5.6230	5.7682	5.9129	6.0530
	4.8808	5.0335	5.1857	5.3337	5.4810	5.6274	5.7726	5.9173	6.0574
	4.8854	5.0381	5.1903	5.3381	5.4855	5.6318	5.7770	5.9217	6.0617
	4.8900	5.0426	5.1948	5.3426	5.4899	5.6362	5.7814	5.9261	6.0661
	4.8945	5.0472	5.1994	5.3470	5.4943	5.6406	5.7858	5.9305	6.0704
	4.8991	5.0517	5.2039	5.3515	5.4988	5.6450	5.7902	5.9349	6.0748
	4.9037	5.0563	5.2085	5.3559	5.5032	5.6494	5.7946	5.9393	6.0791
	4.9083	5.0608	5.2130	5.3604	5.5076	5.6538	5.7990	5.9437	6.0835
	4.9129	5.0654	5.2176	5.3648	5.5120	5.6582	5.8034	5.9481	6.0878
	4.9175	5.0699	5.2221	5.3693	5.5165	5.6626	5.8078	5.9525	6.0922
	4.9221	5.0745	5.2267	5.3737	5.5209	5.6670	5.8122	5.9569	6.0965
	4.9266	5.0790	5.2312	5.3782	5.5253	5.6714	5.8166	5.9613	6.1009
	4.9312	5.0836	5.2358	5.3826	5.5297	5.6758	5.8210	5.9657	6.1052
	4.9358	5.0881	5.2403	5.3871	5.5341	5.6802	5.8254	5.9701	6.1096
	4.9404	5.0927	5.2449	5.3915	5.5386	5.6846	5.8298	5.9745	6.1139
	4.9450	5.0972	5.2494	5.3960	5.5430	5.6890	5.8342	5.9789	6.1183
	4.9496	5.1018	5.2540	5.4004	5.5474	5.6934	5.8386	5.9833	6.1226
	4.9542	5.1063	5.2585	5.4049	5.5518	5.6978	5.8430	5.9877	6.1270
	4.9588	5.1109	5.2631	5.4093	5.5562	5.7022	5.8474	5.9921	6.1313
	4.9634	5.1154	5.2676	5.4138	5.5606	5.7066	5.8518	5.9965	6.1357
	4.9680	5.1200	5.2722	5.4182	5.5650	5.7110	5.8562	6.0009	6.1400
	4.9726	5.1245	5.2767	5.4227	5.5694	5.7154	5.8606	6.0053	6.1444
	4.9772	5.1291	5.2813	5.4271	5.5738	5.7198	5.8650	6.0097	6.1487
	4.9818	5.1336	5.2858	5.4316	5.5782	5.7242	5.8694	6.0141	6.1531
	4.9864	5.1382	5.2904	5.4360	5.5826	5.7286	5.8738	6.0185	6.1574
	4.9910	5.1427	5.2949	5.4405	5.5870	5.7330	5.8782	6.0229	6.1618
	4.9956	5.1473	5.2995	5.4449	5.5914	5.7374	5.8826	6.0273	6.1661
	5.0002	5.1518	5.3040	5.4494	5.5958	5.7418	5.8870	6.0317	6.1705
	5.0048	5.1564	5.3086	5.4538	5.6002	5.7462	5.8914	6.0361	6.1748
	5.0094	5.1609	5.3131	5.4583	5.6046	5.7506	5.8958	6.0405	6.1792
	5.0140	5.1655	5.3177	5.4627	5.6090	5.7550	5.9002	6.0449	6.1835
	5.0186	5.1700	5.3222	5.4672	5.6134	5.7594	5.9046	6.0493	6.1879
	5.0232	5.1746	5.3268	5.4716	5.6178	5.7638	5.9090	6.0537	6.1922
	5.0278	5.1791	5.3313	5.4761	5.6222	5.7682	5.9134	6.0581	6.1966
	5.0324	5.1837	5.3359	5.4805	5.6266	5.7726	5.9178	6.0625	6.2009
	5.0370	5.1882	5.3404	5.4850	5.6310	5.7770	5.9222	6.0669	6.2053
	5.0416	5.1928	5.3450	5.4894	5.6354	5.7814	5.9266	6.0713	6.2096
	5.0462	5.1973	5.3495	5.4939	5.6398	5.7858	5.9310	6.0757	6.2140
	5.0508	5.2019	5.3541	5.4983	5.6442	5.7902	5.9354	6.0801	6.2183
	5.0554	5.2064	5.3586	5.5028	5.6486	5.7946	5.9398	6.0845	6.2227
	5.0600	5.2110	5.3632	5.5072	5.6530	5.7990	5.9442	6.0889	6.2270
	5.0646	5.2155	5.3677	5.5117	5.6574	5.8034	5.9486	6.0933	6.2314
	5.0692	5.2201	5.3723	5.5161	5.6618	5.8078	5.9530	6.0977	6.2357
	5.0738	5.2246	5.3768	5.5206	5.6662	5.8122	5.9574	6.1021	6.2401
	5.0784	5.2292	5.3814	5.5250	5.6706	5.8166	5.9618	6.1065	6.2444
	5.0830	5.2337	5.3859	5.5295	5.6750	5.8210	5.9662	6.1109	6.2488
	5.0876	5.2383	5.3905	5.5339	5.6794	5.8254	5.9706	6.1153	6.2531
	5.0922	5.2428	5.3950	5.5384	5.6838	5.8298	5.9750	6.1197	6.2575
	5.0968	5.2474	5.3996	5.5428	5.6882	5.8342	5.9794	6.1241	6.2618
	5.1014	5.2519	5.4041	5.5473	5.6926	5.8386	5.9838	6.1285	6.2662
	5.1060	5.2565	5.4087	5.5517	5.6970	5.8430	5.9882	6.1329	6.2705
	5.1106	5.2610	5.4132	5.5562	5.7014	5.8474	5.9926	6.1373	6.2749
	5.1152	5.2656	5.4178	5.5606	5.7058	5.8518	5.9970	6.1417	6.2792
	5.1198	5.2701	5.4223	5.5650	5.7102	5.8562	6.0014	6.1461	6.2836
	5.1244	5.2747	5.4269	5.5695	5.7147	5.8606	6.0058	6.1505	6.2879
	5.1290	5.2792	5.4314	5.5739	5.7191	5.8650	6.0102	6.1549	6.2923
	5.1336	5.2838	5.4360	5.5784	5.7235	5.8694	6.0146	6.1593	6.2966
	5.1382	5.2883	5.4405	5.5828	5.7279	5.8738	6.0190	6.1637	6.3010
	5.1428	5.2929	5.4451	5.5872	5.7323	5.8782	6.0234	6.1681	6.3053
	5.1474	5.2974	5.4496	5.5917	5.7367	5.8826	6.0278	6.1725	6.3097
	5.1520	5.3020	5.4542	5.5961	5.7411	5.8870	6.0322	6.1769	6.3140
	5.1566	5.3065	5.4587	5.6005	5.7455	5.8914	6.0366	6.1813	6.3184
	5.1612	5.3111	5.4633	5.6050	5.7499	5.8958	6.0410	6.1857	6.3227
	5.1658	5.3156	5.4678	5.6094	5.7543	5.9002	6.0454	6.1901	6.3271
	5.1704	5.3202	5.4724	5.6138	5.7587	5.9046	6.0498	6.1945	6.3314
	5.1750	5.3247	5.4769	5.6183	5.7631	5.9090	6.0542	6.1989	6.3358
	5.1796	5.3293	5.4815	5.6227	5.7675	5.9134	6.0586	6.2033	6.3401
	5.1842	5.3338	5.4860	5.6271	5.7719	5.9178	6.0630	6.2077	6.3445
	5.1888	5.3384	5.4906	5.6316	5.7763	5.9222	6.0674	6.2121	6.3488
	5.1934	5.3429	5.4951	5.6360	5.7807	5.9266	6.0718	6.2165	6.3532
	5.1980	5.3475	5.4997	5.6404	5.7851	5.9310	6.0762	6.2209	6.3575
	5.2026	5.3520	5.5042	5.6449	5.7895	5.9354	6.0806	6.2253	6.3619
	5.2072	5.3566	5.5088	5.6493	5.7939	5.9398	6.0850	6.2297	6.3662
	5.2118	5.3611	5.5133	5.6537	5.7983	5.9442	6.0894	6.2341	6.3706
	5.2164	5.3657	5.5179	5.6582	5.8027	5.9486	6.0938	6.2385	6.3749
	5.2210	5.3702	5.5224	5.6626	5.8071	5.9530	6.0982	6.2429	6.3793
	5.2256	5.3748	5.5270	5.6670	5.8115	5.9574	6.1026	6.2473	6.3836
	5.2302	5.3793	5.5315	5.6714	5.8159	5.9618	6.1070	6.2517	6.3880
	5.2348	5.3839	5.5361	5.6759	5.8203	5.9662	6.1114	6.2561	6.3923
	5.2394	5.3884	5.5406	5.6803	5.8247	5.9706	6.1158	6.2605	6.3967
	5.2440	5.3930	5.5452	5.6847	5.8291	5.9750	6.1202	6.2649	6.4010
	5.2486	5.3975	5.5497	5.6891	5.8335	5.9794	6.1246	6.2693	6.4054
	5.2532	5.4021	5.5543	5.6936	5.8379	5.9838	6.1290	6.2737	6.4097
	5.2578	5.4066	5.5588	5.6980	5.8423	5.9882	6.1334	6.2781	6.4141
	5.2624	5.4112	5.5634	5.7024	5.8467	5.9926	6.1378	6.2825	6.4184
	5.2670	5.4157	5.5679	5.7068	5.8511	5.9970	6.1422	6.2869	6.4228
	5.2716	5.4203	5.5725	5.7113	5.8555	6.0014	6.1466	6.2913	6.4271
	5.2762	5.4248	5.5770	5.7157	5.8599	6.0058	6.1510	6.2957	6.4315
	5.2808	5.4294	5.5816	5.7201	5.8643	6.0102	6.1554	6.3001	6.4358
	5.2854	5.4339	5.5861	5.7245	5.8687	6.0146	6.1598	6.3045	6.4402
	5.2900	5.4385	5.5907	5.7290	5.8731	6.0190	6.1642	6.3089	6.4445
	5.2946	5.4430	5.5952	5.7334	5.8775	6.0234	6.1686	6.3133	6.4489
	5.2992	5.4476	5.5998	5.7378	5.8819	6.0278	6.1730	6.3177	6.4532
	5.3038	5.4521	5.6043	5.7422	5.8863	6.0322	6.1774	6.3221	6.4576
	5.3084	5.4567	5.6089	5.7466	5.8907	6.0366	6.1818	6.3265	6.4619
	5.3130	5.4612	5.6134	5.7510	5.8951	6.0410	6.1862	6.3309	6.4663
	5.3176	5.4658	5.6180	5.7554	5.8995	6.0454	6.1906	6.3353	6.4706
	5.3222	5.4703	5.6225	5.7598	5.9039	6.0498	6.1950	6.3397	6.4750
	5.3268	5.4749	5.6271	5.7642	5.9083	6.0542	6.1994	6.3441	6.4793
	5.3314	5.4794	5.6316	5.7686	5.9127	6.0586	6.2038	6.3485	6.4837
	5.3360	5.4840	5.6362	5.7730	5.9171	6.0630	6.2082	6.3529	6.4880
	5.3406	5.4885	5.6407	5.7774	5.9215	6.0674	6.2126	6.3573	6.4924
	5.3452	5.4931	5.6453	5.7818	5.9259	6.0718	6.2170	6.3617	6.4967
	5.3498	5.4976	5.6498	5.7862	5.9303	6.0762	6.2214	6.3661	6.5011
	5.3544	5.5022	5.6544	5.7906	5.9347	6.0806	6.2258	6.3705	6.5054
	5.3590	5.5067	5.6589	5.7950	5.9391	6.0850	6.2302	6.3749	6.5098
	5.3636	5.5113	5.6635	5.7994	5.9435	6.0894	6.2346	6.3793	6.5141
	5.3682	5.5158	5.6680	5.8038	5.9479	6.0938	6.2390	6.3837	6.5185
	5.3728	5.5204	5.6726	5.8082	5.9523	6.0982	6.2434	6.3881	6.5228
	5.3774	5.5249	5.6771	5.8126	5.9567	6.1026	6.2478	6.3925	6.5272
	5.3820	5.5295	5.6817	5.8170	5.9611	6.1070	6.2522	6.3969	6.5315
	5.3866	5.5340	5.6862	5.8214	5.9655	6.1114	6.2566	6.4013	6.5359
	5.3912	5.5386	5.6908	5.8258	5.9699	6.1158	6.2610	6.4057	6.5402
	5.3958	5.5431	5.6953	5.8302	5.9743	6.1202	6.2654	6.4101	6.5446
	5.4004	5.5477	5.6999	5.8346	5.9787	6.1246	6.2698	6.4145	6.5489
	5.4050	5.5522	5.7044	5.8390	5.9831	6.1290	6.2742	6.4189	6.5533
	5.4096	5.5568	5.7090	5.8434	5.9875	6.1334	6.2786	6.4233	6.5576
	5.4142	5.5613	5.7135	5.8478	5.9919	6.1378	6.2830	6.4277	6.5620
	5.4188	5.5659	5.7181	5.8522	5.9963	6.1422	6.2874	6.4321	6.5663
	5.4234	5.5704	5.7226	5.8566	6.0007	6.1466	6.2918	6.4365	6.5707
	5.4280	5.5750	5.7272	5.8610	6.0051	6.1510	6.2962	6.4409	6.5750
	5.4326	5.5795	5.7317	5.8654	6.0095	6.1554	6.3006	6.4453	6.5794
	5.4372	5.5841	5.7363	5.8698	6.0139	6.1598	6.3050	6.4497	6.5837
	5.4418	5.5886	5.7408	5.8742	6.0183	6.1642	6.3094	6.4541	6.5881
	5.4464	5.5932	5.7454	5.8786	6.0227	6.1686	6.3138	6.4585	6.5924
	5.4510	5.5977	5.7499	5.8830	6.0271	6.1730	6.3182	6.4629	6.5968
	5.4556	5.6023	5.7545	5.8874	6.0315	6.1774	6.3226	6.4673	6.6011
	5.4602	5.6068	5.7590	5.8918	6.0359	6.1818	6.3270	6.4717	6.6055
	5.4648	5.6114	5.7636	5.8962	6.0403	6.1862	6.3314	6.4761	6.6098
	5.4694	5.6159	5.7681	5.9006	6.0447	6.1906	6.3358	6.4805	6.6142
	5.4740	5.6205	5.7727	5.9050	6.0491	6.1950	6.3402	6.4849	6.6185
	5.4786	5.6250	5.7772	5.9094	6.0535	6.1994	6.3446	6.4893	6.6229
	5.4832	5.6296	5.7818	5.9138	6.0579	6.2038	6.3490	6.4937	6.6272
	5.4878	5.6341	5.7863	5.9182	6.0623	6.2082	6.3534	6.4981	6.6316
	5.4924	5.6387	5.7909	5.9226	6.0667	6.2126	6.3578	6.5025	6.6359
	5.4970	5.6432	5.7954	5.9270	6.0711	6.2170	6.3622	6.5069	6.6403
	5.5016	5.6478	5.8000	5.9314	6.0755	6.2214	6.3666	6.5113	6.6446
	5.5062	5.6523	5.8045	5.9358	6.0799	6.2258	6.3710	6.5157	6.6490
	5.5108	5.6569	5.8091	5.9402	6.0843	6.2302	6.3754	6.5201	6.6533
	5.5154	5.6614	5.8136	5.9446	6.0887	6.2346	6.3798	6.5245	6.6577
	5.5200	5.6660	5.8182	5.9490	6.0931	6.2390	6.3842	6.5289	6.6620
	5.5246	5.6705	5.8227	5.9534	6.0975	6.2434	6.3886	6.5333	6.6664
	5.5292	5.6751	5.8273	5.9578	6.1019	6.2478	6.3930	6.5377	6.6707
	5.5338	5.6796	5.8318	5.9622	6.1063	6.2522	6.3974	6.5421	6.6751
	5.5384	5.6842	5.8364	5.9666	6.1107	6.2566	6.4018	6.5465	6.6794
	5.5430	5.6887	5.8409	5.9710	6.1151	6.2610	6.4062	6.5509	6.6838
	5.5476	5.6933	5.8455	5.9754	6.1195	6.2654	6.4106	6.5553	6.6881
	5.5522	5.6978	5.8500	5.9798	6.1239	6.2698	6.4150	6.5597	6.6925
	5.5568	5.7024	5.8546	5.9842	6.1283	6.2742	6.4194	6.5641	6.6968
	5.5614	5.7069	5.8591	5.9886	6.1327	6.2786	6.4238	6.5685	6.7012
	5.5660	5.7115	5.8637	5.9930	6.1371	6.2830	6.4282	6.5729	6.7055
	5.5706	5.7160	5.8682	5.9974	6.1415	6.2874	6.4326	6.5773	6.7099
	5.5752	5.7206	5.8728	6.0018	6.1459	6.2918	6.4370	6.5817	6.7142
	5.5798	5.7251	5.8773	6.0062	6.1503	6.2962	6.4414	6.5861	6.7186
	5.5844	5.7297	5.8819	6.0106	6.1547	6.3006	6.4458	6.5905	6.7229
	5.5890	5.7342	5.8864	6.0150	6.1591	6.3050	6.4502	6.5949	6.7273
	5.5936	5.7388	5.8910	6.0194	6.1635	6.3094	6.4546	6.5993	6.7316
	5.5982	5.7433	5.8955	6.0238	6.1679	6.3138	6.4590	6.6037	6.7360
	5.6028	5.7479	5.9001	6.0282	6.1723	6.3182	6.4634	6.6081	6.7403
	5.6074	5.7524	5.9046	6.0326	6.1767	6.3226	6.4678	6.6125	6.7447
	5.6120	5.7570	5.9092	6.0370	6.1811	6.3270	6.4722	6.6169	6.7490
	5.6166	5.7615	5.9137	6.0414	6.1855	6.3314	6.4766	6.6213	6.7534
	5.6212	5.7661	5.9183	6.0458	6.1899	6.3358	6.4810	6.6257	6.7577
	5.6258	5.7706	5.9228	6.0502	6.1943	6.3402	6.4854	6.6301	6.7621
	5.6304	5.7752	5.9274	6.0546	6.1987	6.3446	6.4898	6.6345	6.7664
	5.6350	5.7797	5.9319	6.0590	6.2031	6.3490	6.4942	6.6389	6.7708
	5.6396	5.7843	5.9365	6.0634	6.2075	6.3534	6.4986	6.6433	6.7751
	5.6442	5.7888	5.9410	6.0678	6.2119	6.3578	6.5030	6.6477	6.7795
	5.6488	5.7934	5.9456	6.0722	6.2163	6.3622	6.5074	6.6521	6.7838
	5.6534	5.7979	5.9501	6.0766	6.2207	6.3666	6.5118	6.6565	6.7882
	5.6580	5.8025	5.9547	6.0810	6.2251	6.3710	6.5162	6.6609	6.7925
	5.6626	5.8070	5.9592	6.0854	6.2295	6.3754	6.5206	6.6653	6.7969
	5.6672	5.8116	5.9638	6.0898	6.2339	6.3798	6.5250	6.6697	6.8012
	5.6718	5.8161	5.9683	6.0942	6.2383	6.3842	6.5294	6.6741	6.8056
	5.6764	5.8207	5.9729	6.0986	6.2427	6.3886	6.5338	6.6785	6.8099
	5.6810	5.8252	5.9774	6.1030	6.2471	6.3930	6.5382	6.6829	6.8143
	5.6856	5.8298	5.9820	6.1074	6.2515	6.3974	6.5426	6.6873	6.8186
	5.6902	5.8343	5.9865	6.1118	6.2559	6.4018	6.5470	6.6917	6.8230
	5.6948	5.8389	5.9911	6.1162	6.2603	6.4062	6.5514	6.6961	6.8273
	5.6994	5.8434	5.9956	6.1206	6.2647	6.4106	6.5558	6.7005	6.8317
	5.7040	5.8480	6.0002	6.1250	6.2691	6.4150	6.5602	6.7049	6.8360
	5.7086	5.8525	6.0047	6.1294	6.2735	6.4194	6.5646	6.7093	6.8404
	5.7132	5.8571	6.0093	6.1338	6.2779	6.4238	6.5690	6.7137	6.8447
	5.7178	5.8616	6.0138	6.1382	6.2823	6.4282	6.5734	6.7181	6

SINE BAR TABLE—*Continued*

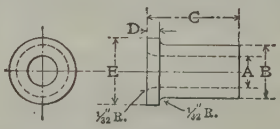
Min.	Constant, 36 Deg.	Constant, 37 Deg.	Constant, 38 Deg.	Constant, 39 Deg.	Constant, 40 Deg.	Constant, 41 Deg.	Constant, 42 Deg.	Constant, 43 Deg.	Constant, 44 Deg.
0	5.8779	6.0182	6.1566	6.2932	6.4279	6.5606	6.6913	6.8200	6.9466
1	5.8802	6.0205	6.1589	6.2955	6.4301	6.5628	6.6935	6.8221	6.9487
2	5.8826	6.0228	6.1612	6.2977	6.4323	6.5650	6.6956	6.8242	6.9508
3	5.8849	6.0251	6.1635	6.3000	6.4346	6.5672	6.6978	6.8264	6.9529
4	5.8873	6.0274	6.1658	6.3022	6.4368	6.5694	6.6999	6.8285	6.9549
5	5.8896	6.0298	6.1681	6.3045	6.4390	6.5716	6.7021	6.8306	6.9570
6	5.8920	6.0321	6.1704	6.3068	6.4412	6.5738	6.7043	6.8327	6.9591
7	5.8943	6.0344	6.1726	6.3090	6.4435	6.5759	6.7064	6.8349	6.9612
8	5.8967	6.0367	6.1749	6.2113	6.4457	6.5781	6.7086	6.8370	6.9633
9	5.8990	6.0390	6.1772	6.3136	6.4479	6.5803	6.7107	6.8391	6.9654
10	5.9014	6.0414	6.1795	6.3158	6.4501	6.5825	6.7129	6.8412	6.9675
11	5.9037	6.0437	6.1818	6.3180	6.4524	6.5847	6.7151	6.8434	6.9690
12	5.9061	6.0460	6.1841	6.3203	6.4546	6.5869	6.7172	6.8455	6.9717
13	5.9084	6.0483	6.1864	6.3225	6.4568	6.5891	6.7194	6.8476	6.9737
14	5.9108	6.0506	6.1887	6.3248	6.4590	6.5913	6.7215	6.8497	6.9758
15	5.9131	6.0529	6.1909	6.3271	6.4612	6.5935	6.7237	6.8518	6.9779
16	5.9154	6.0553	6.1932	6.3293	6.4635	6.5956	6.7258	6.8539	6.9800
17	5.9178	6.0576	6.1965	6.3316	6.4657	6.5978	6.7280	6.8561	6.9821
18	5.9201	6.0599	6.1978	6.3338	6.4679	6.6000	6.7301	6.8582	6.9842
19	5.9225	6.0622	6.2001	6.3361	6.4701	6.6022	6.7323	6.8603	6.9862
20	5.9248	6.0645	6.2024	6.3383	6.4723	6.6044	6.7344	6.8624	6.9885
21	5.9272	6.0668	6.2046	6.3400	6.4746	6.6066	6.7366	6.8645	6.9904
22	5.9295	6.0691	6.2069	6.3428	6.4768	6.6088	6.7387	6.8666	6.9925
23	5.9318	6.0714	6.2092	6.3451	6.4790	6.6109	6.7409	6.8688	6.9946
24	5.9342	6.0738	6.2115	6.3473	6.4812	6.6131	6.7430	6.8709	6.9966
25	5.9365	6.0761	6.2138	6.3496	6.4834	6.6153	6.7452	6.8730	6.9987
26	5.9389	6.0784	6.2160	6.3518	6.4856	6.6175	6.7473	6.8751	7.0008
27	5.9412	6.0807	6.2183	6.3540	6.4878	6.6197	6.7495	6.8772	7.0029
28	5.9436	6.0830	6.2206	6.3563	6.4901	6.6218	6.7516	6.8793	7.0049
29	5.9459	6.0853	6.2229	6.3585	6.4923	6.6240	6.7538	6.8814	7.0070
30	5.9482	6.0876	6.2251	6.3608	6.4945	6.6262	6.7559	6.8835	7.0091

31	5.9506	6.0869	6.2274	6.3630	6.4967	6.6284	6.7580	6.8857	7.0112
32	5.9529	6.0922	6.2297	6.3653	6.4989	6.6306	6.7602	6.8878	7.0132
33	5.9552	6.0945	6.2320	6.3675	6.5011	6.6327	6.7623	6.8899	7.0153
34	5.9576	6.0968	6.2342	6.3698	6.5033	6.6349	6.7645	6.8920	7.0174
35	5.9599	6.0991	6.2365	6.3720	6.5055	6.6371	6.7666	6.8941	7.0195
36	5.9622	6.1015	6.2388	6.3742	6.5077	6.6393	6.7688	6.8962	7.0215
37	5.9646	6.1038	6.2411	6.3765	6.5100	6.6414	6.7709	6.8983	7.0236
38	5.9669	6.1061	6.2433	6.3787	6.5122	6.6436	6.7730	6.9004	7.0257
39	5.9693	6.1084	6.2456	6.3810	6.5144	6.6458	6.7752	6.9025	7.0277
40	5.9716	6.1107	6.2479	6.3832	6.5166	6.6480	6.7773	6.9046	7.0298
41	5.9739	6.1130	6.2502	6.3854	6.5188	6.6501	6.7795	6.9067	7.0319
42	5.9763	6.1153	6.2524	6.3877	6.5210	6.6523	6.7816	6.9088	7.0339
43	5.9786	6.1176	6.2547	6.3899	6.5232	6.6545	6.7837	6.9109	7.0360
44	5.9809	6.1199	6.2570	6.3922	6.5254	6.6566	6.7859	6.9130	7.0381
45	5.9833	6.1222	6.2592	6.3944	6.5276	6.6588	6.7880	6.9151	7.0401
46	5.9856	6.1245	6.2615	6.3966	6.5298	6.6610	6.7901	6.9172	7.0422
47	5.9879	6.1268	6.2638	6.3989	6.5320	6.6632	6.7923	6.9193	7.0443
48	5.9902	6.1291	6.2660	6.4011	6.5342	6.6653	6.7944	6.9214	7.0463
49	5.9926	6.1314	6.2683	6.4033	6.5364	6.6675	6.7965	6.9235	7.0484
50	5.9949	6.1337	6.2706	6.4056	6.5386	6.6697	6.7987	6.9256	7.0505
51	5.9972	6.1360	6.2728	6.4078	6.5408	6.6718	6.8008	6.9277	7.0525
52	5.9995	6.1383	6.2751	6.4100	6.5430	6.6740	6.8029	6.9298	7.0546
53	6.0019	6.1406	6.2774	6.4123	6.5452	6.6762	6.8051	6.9319	7.0567
54	6.0042	6.1429	6.2796	6.4145	6.5474	6.6783	6.8072	6.9340	7.0587
55	6.0065	6.1451	6.2819	6.4167	6.5496	6.6805	6.8093	6.9361	7.0608
56	6.0089	6.1474	6.2842	6.4190	6.5518	6.6827	6.8115	6.9382	7.0628
57	6.0112	6.1497	6.2864	6.4212	6.5540	6.6848	6.8136	6.9403	7.0649
58	6.0135	6.1520	6.2887	6.4234	6.5562	6.6870	6.8157	6.9424	7.0670
59	6.0158	6.1543	6.2909	6.4256	6.5584	6.6891	6.8179	6.9445	7.0690
60	6.0182	6.1566	6.2932	6.4279	6.5606	6.6913	6.8200	6.9466	7.0711

STANDARD JIG PARTS

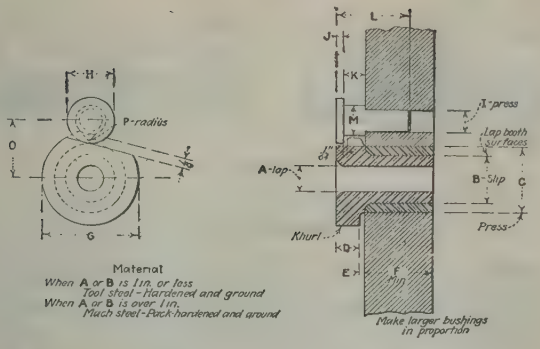
Drill Bushings

Two different styles of bushings with their dimensions are shown. These can be blanked out in quantities and finished to required sizes as needed, and should be made of tool steel. Allowances should be made in the blanks for grinding and lapping after



A	B	C	D	E	A	B	C	D	E
1/4	7/16	1 1/16	3/32	1/16	1 1/16	1 5/16	1 1/16	1/8	1 1/8
5/16	1/2	3/4	3/32	5/8	3/4	1	1 1/8	1/8	1 3/16
3/8	9/16	1 3/16	3/32	1 1/16	1 3/16	1 1/16	1 3/16	1/8	1 1/4
7/16	5/8	1 5/16	3/32	3/4	7/8	1 1/8	1 1/4	5/32	1 5/16
1/2	11/16	7/8	3/32	1 3/16	1 5/16	1 3/16	1 5/16	5/32	1 3/8
9/16	3/4	1 5/16	1/8	7/8	1	1 1/4	1 5/16	5/32	1 7/16
5/8	7/8	1	1/8	1 1/16					

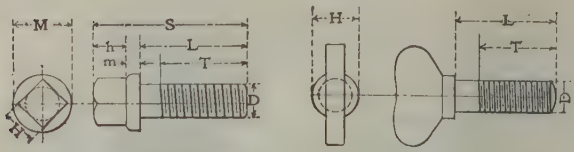
hardening. Fig. 1 shows a slip bushing; Fig. 2 a stationary bushing, and Fig. 3 a stationary bushing where tools with stop collars are to be used. Such bushings as shown in Figs. 2 and 3 are also used for linings for slip bushings.



Drill Bushings, "Slip" Type

In Inches

| | | |



Binding Screws

Binding screws should be made in various sizes and with threads to conform to the standard taps with which the shop is provided. When drills of a very large size are used, a screw with a square or hexagon head is best, as the work requires firm clamping. If the drills used are small, a winged screw will be sufficient and more convenient, as it will require less time to manipulate. Some good screws for clamping straps are shown in Figs. 4 and 5. Of course the screws can be made of any length desired.

When the work is to be held against the seat or a stop by means of a set-screw, such screws as shown in Figs. 6 and 7 will be found very useful. If, however, the work is very light, a wing screw can be used.



D	Thrd.	L	h	I	C	H	S	D	Thrd.	L	W	d
$\frac{1}{4}$	20	1	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{1}{4}$	$1\frac{1}{4}$	$\frac{1}{4}$	20	$\frac{3}{4}$	.040	$\frac{3}{32}$
$\frac{5}{16}$	18	1	$\frac{5}{16}$	$\frac{1}{8}$	$\frac{13}{64}$	$\frac{5}{16}$	$1\frac{5}{16}$	$\frac{5}{16}$	18	1	.057	$\frac{1}{32}$
$\frac{3}{8}$	16	$1\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{17}{64}$	$\frac{3}{8}$	$1\frac{3}{8}$	$\frac{3}{8}$	16	1	$\frac{1}{16}$	$\frac{1}{8}$
$\frac{7}{16}$	14	$1\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{7}{16}$	$1\frac{15}{16}$	$\frac{7}{16}$	14	$1\frac{1}{2}$	$\frac{5}{64}$	$\frac{1}{8}$
$\frac{1}{2}$	13	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{11}{32}$	$\frac{1}{2}$	2	$\frac{1}{2}$	13	$1\frac{1}{2}$	$\frac{5}{64}$	$\frac{1}{8}$

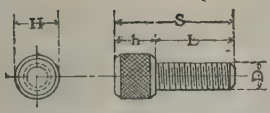


FIG. 8.

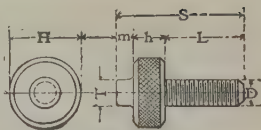


FIG. 9.

Locking Screws

A convenient hinge-cover locking screw is shown in Fig. 10. This screw, when used, should be adjusted so that only a quarter turn will be needed to clamp or release the cover, which should be slotted to admit the head of the screw.

The different sizes of the styles of screws shown are not only used with drilling jigs, but are equally useful with other jigs and fixtures. These screws should be made of screw stock and case-hardened.

D	Thrd.	L	h	S	H	D	Thrd.	L	h	m	S	H	T
$\frac{1}{4}$	20	$\frac{3}{4}$	$\frac{3}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	20	$\frac{3}{4}$	$\frac{5}{16}$	$\frac{3}{16}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{4}$
$\frac{5}{16}$	18	1	$\frac{3}{8}$	$1\frac{1}{2}$	$\frac{5}{16}$	$\frac{5}{16}$	18	1	$\frac{3}{8}$	$\frac{1}{4}$	$1\frac{9}{16}$	$\frac{7}{8}$	$\frac{5}{16}$
$\frac{3}{8}$	16	1	$\frac{7}{16}$	$1\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{8}$	16	1	$\frac{7}{16}$	$\frac{1}{4}$	$1\frac{11}{16}$	1	$\frac{3}{8}$

Strap Dimensions

A convenient strap to use with these jigs is shown in Fig. 11. The straps should be made of low-carbon steel and case-hardened after finishing. The slot *G* can be located in the proper position and made of such dimensions as to allow the strap to be slipped back out of the way when work is being placed in and taken from the jig.

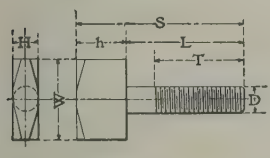


FIG. 10.

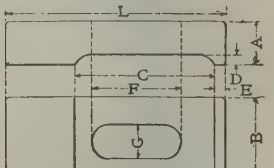
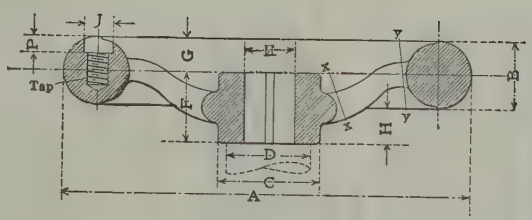
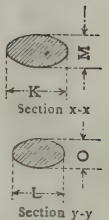


FIG. 11.

D	Thrd.	H	h	L	S	T	W	A	B	C	D	E	L
$\frac{5}{16}$	18	$\frac{1}{8}$	$\frac{5}{8}$	$1\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{5}{16}$	$\frac{1}{2}$	1	$1\frac{5}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$2\frac{1}{2}$
$\frac{3}{8}$	16	$\frac{3}{16}$	$\frac{11}{16}$	$1\frac{7}{8}$	$2\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{16}$	$\frac{1}{2}$	1	$1\frac{7}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	3
$\frac{7}{16}$	14	$\frac{7}{16}$	$\frac{3}{4}$	$1\frac{7}{8}$	$2\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{16}$	$\frac{1}{2}$	$1\frac{1}{4}$	2	$\frac{1}{8}$	$\frac{1}{16}$	$3\frac{1}{2}$
$\frac{1}{2}$	13	$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{7}{8}$	$2\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{16}$	$\frac{1}{2}$	$1\frac{1}{4}$	2	$\frac{1}{8}$	$\frac{1}{16}$	$3\frac{1}{2}$
													4

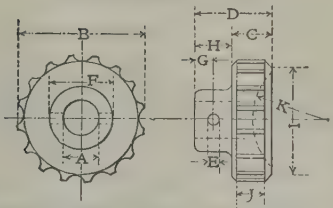




HAND WHEELS. (Pratt & Whitney Co.)

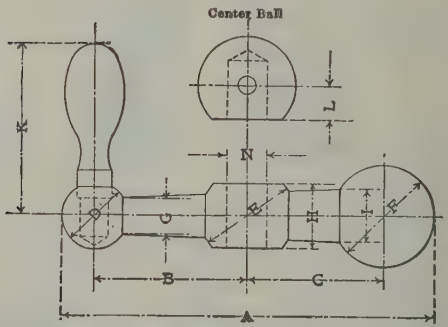
A	B	C	D	E	F	G	H	J	K	L	M	O	P	Tap	Spline	Handle No.	No. of Arms
3 in.	$\frac{5}{8}$	$1\frac{1}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{15}{32}$	$1\frac{3}{32}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{5}{16}$ — 28	$\frac{1}{16} \times \frac{1}{32}$	00	3
4		$1\frac{3}{16}$												$\frac{5}{16}$ — 28	$\frac{1}{16} \times \frac{3}{32}$	0	3
$4\frac{1}{2}$	$1\frac{1}{8}$		I	$1\frac{1}{16}$	$\frac{5}{8}$	$1\frac{5}{16}$	$\frac{9}{16}$	$1\frac{1}{16}$	$\frac{15}{32}$	$1\frac{7}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$ — 24	$\frac{3}{32} \times \frac{1}{32}$	1	3
5	$1\frac{3}{16}$	$1\frac{5}{16}$	$1\frac{1}{16}$	$1\frac{3}{16}$	$\frac{3}{4}$	$1\frac{7}{16}$	$\frac{5}{8}$	$1\frac{3}{16}$	$\frac{15}{32}$	$1\frac{7}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$ — 24	$\frac{3}{32} \times \frac{3}{32}$	1	3
6	I	$1\frac{7}{16}$	$1\frac{1}{8}$	$1\frac{5}{16}$	$\frac{7}{8}$	$1\frac{9}{16}$	$\frac{11}{16}$	$1\frac{5}{16}$	$\frac{15}{32}$	$1\frac{7}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$ — 24	$\frac{3}{32} \times \frac{1}{16}$	1	3
7	I	$1\frac{1}{2}$	$1\frac{3}{16}$	$1\frac{7}{16}$	I	$1\frac{11}{16}$	$\frac{3}{4}$	$1\frac{7}{16}$	$\frac{15}{32}$	$1\frac{7}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$ — 24	$\frac{1}{8} \times \frac{1}{16}$	2	3
8	$1\frac{1}{16}$	$1\frac{9}{16}$	$1\frac{1}{4}$	$1\frac{9}{16}$	$1\frac{1}{16}$	$1\frac{13}{16}$	$\frac{13}{16}$	$1\frac{9}{16}$	$\frac{15}{32}$	$1\frac{7}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$ — 24	$\frac{1}{8} \times \frac{1}{16}$	3	3
9	$1\frac{1}{8}$	$1\frac{5}{8}$	$1\frac{5}{16}$	$1\frac{5}{8}$	$1\frac{1}{8}$	$1\frac{7}{8}$	$\frac{7}{8}$	$1\frac{5}{8}$	$\frac{15}{32}$	$1\frac{7}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$ — 24	$\frac{1}{8} \times \frac{1}{16}$	4	3
10	$1\frac{3}{16}$	$1\frac{11}{16}$	$1\frac{3}{8}$	$1\frac{11}{16}$	$1\frac{3}{16}$	$1\frac{15}{16}$	$\frac{15}{16}$	$1\frac{11}{16}$	$\frac{15}{32}$	$1\frac{7}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$ — 24	$\frac{1}{8} \times \frac{1}{16}$	4	3
11	$1\frac{1}{4}$	$1\frac{13}{16}$	$1\frac{7}{16}$	$1\frac{13}{16}$	$1\frac{1}{4}$	$2\frac{1}{16}$	I	$1\frac{13}{16}$	$\frac{15}{32}$	$1\frac{7}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$ — 20	$\frac{3}{32} \times \frac{3}{32}$	5	3
12	$1\frac{5}{16}$	2	$1\frac{1}{2}$	2	$1\frac{5}{16}$	$2\frac{1}{8}$	$1\frac{1}{16}$	I	$\frac{15}{32}$	$1\frac{7}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$ — 20	$\frac{3}{32} \times \frac{3}{32}$	5	3
	$1\frac{7}{16}$		$1\frac{5}{8}$		$1\frac{3}{8}$	$2\frac{3}{16}$	$1\frac{1}{8}$	$1\frac{1}{16}$	$\frac{15}{32}$	$1\frac{7}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$ — 16	$\frac{1}{16} \times \frac{1}{32}$	6	3

Knobs



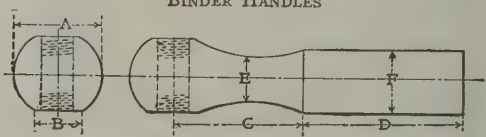
A	B	C	D	E	F	G	H	I	J	K
$\frac{3}{16}$	1	$\frac{8}{16}$	$\frac{15}{32}$	$\frac{3}{32}$	$\frac{7}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{15}{16}$	$\frac{5}{32}$	Cup Out to Suit
$\frac{1}{4}$	$1\frac{3}{16}$	$\frac{5}{16}$	$\frac{11}{16}$	$\frac{3}{32}$	$\frac{9}{16}$	$\frac{3}{16}$	$\frac{3}{8}$	$1\frac{1}{16}$	$\frac{1}{4}$	
$\frac{5}{16}$	$1\frac{3}{16}$	$\frac{5}{16}$	$\frac{11}{16}$	$\frac{1}{8}$	$\frac{9}{16}$	$\frac{3}{16}$	$\frac{3}{8}$	$1\frac{1}{16}$	$\frac{1}{4}$	
$\frac{3}{8}$	$1\frac{1}{2}$	$\frac{7}{16}$	$\frac{7}{8}$	$\frac{1}{8}$	$\frac{11}{16}$	$\frac{7}{32}$	$\frac{7}{16}$	$1\frac{3}{8}$	$\frac{3}{8}$	
$\frac{7}{16}$	$1\frac{1}{2}$	$\frac{7}{16}$	$\frac{7}{8}$	$\frac{1}{8}$	$\frac{11}{16}$	$\frac{7}{32}$	$\frac{7}{16}$	$1\frac{3}{8}$	$\frac{3}{8}$	
$\frac{1}{2}$	$1\frac{3}{4}$	$\frac{9}{16}$	$1\frac{1}{16}$	$\frac{5}{32}$	$\frac{7}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$1\frac{5}{8}$	$\frac{7}{16}$	
$\frac{9}{16}$	$1\frac{3}{4}$	$\frac{9}{16}$	$1\frac{1}{16}$	$\frac{3}{16}$	$\frac{1}{1}$	$\frac{1}{4}$	$\frac{1}{2}$	$1\frac{5}{8}$	$\frac{7}{16}$	
$\frac{5}{8}$	$2\frac{1}{4}$	$\frac{11}{16}$	$1\frac{1}{4}$	$\frac{3}{16}$	$1\frac{1}{16}$	$\frac{9}{32}$	$\frac{9}{16}$	$2\frac{1}{16}$	$\frac{5}{8}$	
$\frac{11}{16}$	$2\frac{1}{4}$	$\frac{11}{16}$	$1\frac{1}{4}$	$\frac{3}{16}$	$1\frac{1}{16}$	$\frac{9}{32}$	$\frac{9}{16}$	$2\frac{1}{16}$	$\frac{5}{8}$	
$\frac{3}{4}$	$2\frac{1}{4}$	$\frac{11}{16}$	$1\frac{1}{4}$	$\frac{3}{16}$	$1\frac{1}{16}$	$\frac{9}{32}$	$\frac{9}{16}$	$2\frac{1}{16}$	$\frac{5}{8}$	

Ball Handles
(Pratt & Whitney Co.)



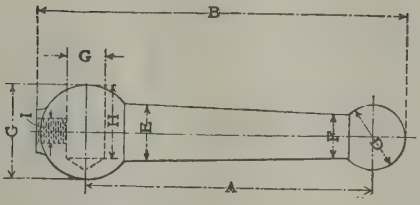
A	B	C	D	E	F	G	H	I	K	L	N
3	1 3/16	1	5/8	7/8	1	8/8	9/16	1/2	1 7/8	9/32	3/8
4	1 3/32	1 1/16	11/16	1	1 1/8	8/8	11/16	9/16	1 11/16	11/32	7/16
4½	1 7/8	1 5/16	3/4	1 3/16	1 1/4	8/8	7/16	5/8	2 1/16	3/8	1/2
5	2 1/16	1 13/16	7/8	1 5/16	1 3/8	1/2	13/16	11/16	2 1/16	13/32	1/2
5½	2 9/32	2 1/32	1 1/16	1 1/4	1 7/16	1/2	7/8	11/16	2 1/4	7/16	9/16
6	2 1/2	2 7/32	1	1 5/16	1 9/16	1/2	15/16	3/4	3 1/8	15/32	9/16
7	2 31/32	2 21/32	1 1/16	1 7/16	1 11/16	9/16	1	13/16	3 11/16	1/2	5/8
8	3 7/16	3 3/32	1 1/8	1 1/2	1 13/16	9/16	1 1/16	7/8	3 5/8	17/32	5/8

Binder Handles



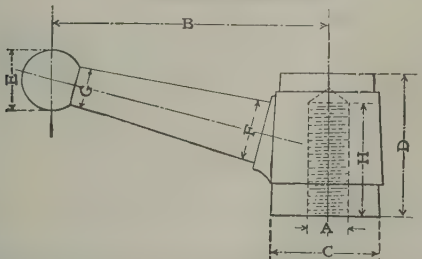
A	B	C	D	E	F	Dia. of Tap
1	3/4	1 5/8	1 5/8	7/16	3/4	7/16
1 1/16	1 3/16	1 3/4	2	1/2	1 3/16	1/2
1 1/4	7/8	2 1/8	2 3/8	9/16	1 5/16	9/16 — 1/2
1 1/2	1 1/8	2 5/8	2 3/4	5/8	1 1/16	5/8 — 1 1/16

Single End Ball Handles



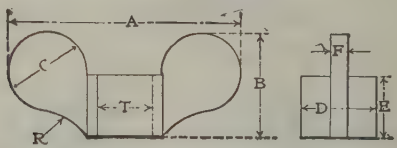
A	B	C	D	E	F	G	H	I
3 1/16	4 5/16	1 1/8	3/4	1 1/16	1/2	7/16	7/8	5/16
3 3/8	4 1/2	1 3/8	7/8	1 1/16	9/16	1/2	1	5/16
4 1/4	5 1/2	1 5/8	7/8	1 1/16	5/8	9/16	1	3/8
4 1/2	6 1/16	1 5/8	1	1	11/16	5/8	1 1/8	3/8
5 3/8	6 1/2	1 3/4	1 1/8	1	11/16	5/8	1 1/8	3/8
6 1/4	7 1/16	2	1 7/16	1 1/8	3/4	3/4	1 1/2	7/16
6 5/8	7 5/16	2	1 1/2	1 3/16	3/4	3/4	1 1/2	7/16
8	9 1/16	2 1/4	1 5/8	1 5/8	7/8	7/8	1 3/4	7/16

Ball Lever Handles



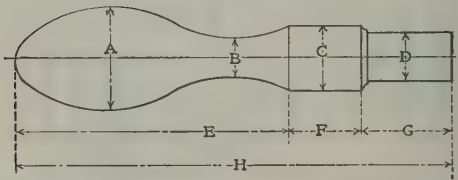
A	B	C	D	E	F	G	H
1/2	2 7/16	1	1 5/8	5/8	1 1/16	1/2	1 3/8
1/2	3 1/16	1 1/8	1 5/8	1 1/16	1 1/16	9/16	1 3/8
5/8	4 3/8	1 3/16	1 5/8	1 1/4	1 1/16	5/8	1 3/8
5/8	5 1/16	1 5/16	2 1/8	1 1/4	1 5/16	5/8	1 3/4
3/4	6 1/2	1 3/8	2 1/2	1	1	5/8	2
3/4	7 1/16	1 3/4	2 1/2	1	1	5/8	2 1/16
3/4	8 1/16	1 3/4	2 7/8	1	1 1/16	5/8	2 7/8

Wing Nuts



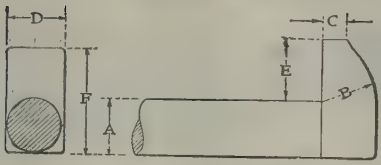
A	B	C	D	E	F	R	T
$\frac{19}{32}$	$\frac{11}{32}$	$\frac{7}{32}$	$\frac{7}{32}$	$\frac{5}{32}$	$\frac{3}{32}$	$\frac{9}{32}$	$\frac{1}{8}$
$\frac{13}{16}$	$\frac{17}{32}$	$\frac{5}{16}$					$\frac{5}{32}$
$\frac{13}{16}$	$\frac{3}{8}$		$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{5}{32}$	
$1\frac{3}{16}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{5}{16}$	$\frac{1}{4}$
$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{5}{32}$	$\frac{7}{16}$	$\frac{5}{16}$
$1\frac{5}{8}$	$\frac{13}{16}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{32}$	$\frac{7}{16}$	$\frac{3}{8}$
$1\frac{15}{16}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{9}{16}$	$\frac{5}{32}$	$\frac{1}{2}$	$\frac{7}{16}$
$2\frac{5}{16}$	$1\frac{1}{16}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{5}{32}$	$\frac{3}{4}$	$\frac{1}{2}$

Machine Handles



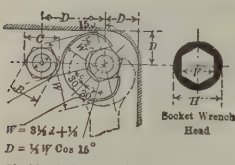
A	B	C	D	E	F	G	H
$\frac{13}{16}$	$\frac{11}{32}$	$\frac{15}{32}$	$\frac{5}{16}$	$1\frac{15}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$2\frac{7}{8}$
$\frac{15}{16}$	$\frac{13}{32}$	$\frac{15}{32}$	$\frac{5}{16}$	2	$\frac{5}{8}$	$\frac{11}{16}$	$3\frac{5}{16}$
1	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{16}$	$2\frac{3}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$3\frac{3}{4}$
$1\frac{3}{16}$	$\frac{15}{32}$	$\frac{19}{32}$	$\frac{5}{16}$	$2\frac{13}{16}$	$\frac{11}{16}$	$\frac{13}{16}$	$4\frac{5}{16}$
$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{19}{32}$	$\frac{5}{16}$	$3\frac{1}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$4\frac{11}{16}$
$1\frac{5}{16}$	$\frac{9}{16}$	$\frac{21}{32}$	$\frac{3}{8}$	$3\frac{7}{16}$	$\frac{7}{8}$	$\frac{13}{16}$	$5\frac{1}{8}$
$1\frac{7}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{16}$	$3\frac{5}{8}$	$\frac{15}{16}$	$1\frac{1}{8}$	$5\frac{11}{16}$

Hook Bolts



Dia. of Bolt	Thickness of Head	Thickness at End	Width of Head	Off Set of Head	Length of Head
A	B	C	D	E	F
$\frac{3}{8}$	$\frac{7}{16}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$1\frac{3}{16}$
$\frac{1}{2}$	$\frac{9}{16}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{9}{16}$	$1\frac{1}{16}$
$\frac{5}{8}$	$\frac{11}{16}$	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$1\frac{5}{16}$
$\frac{3}{4}$	$\frac{13}{16}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$1\frac{9}{16}$
$\frac{7}{8}$	$\frac{15}{16}$	$\frac{7}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	$1\frac{13}{16}$
1	$1\frac{1}{16}$	$\frac{1}{2}$	1	$1\frac{1}{16}$	$2\frac{1}{16}$

Minimum Spacing of Hexagon Nuts for Wrench Clearance



$W = 3\frac{1}{2}d + \frac{1}{8}$

$D = \frac{1}{2}W \cos 15°$

$H = \frac{1}{2}W + \frac{1}{2}C + \frac{1}{2}D$

This shows the minimum spacing for wrench clearance of bolts with hexagon nuts; also the sizes for standard socket-wrench heads, diameter of spot-facing cutters, washers and other information on bolts.

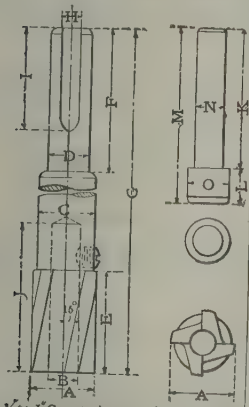
OPEN END AND SOCKET-WRENCH HEADS—ALL DIMENSIONS IN INCHES

Bolt Diam. U.S.S. d	D	D_1	Diam. Spot-facing Cutter	Diam. U. S. S. Washer	Over Flats B	Across Corner C	Socket F	Wrench H
$\frac{1}{4}$	$\frac{1}{2}$	1	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{1}{2}$	.578	$\frac{33}{64}$	$\frac{3}{4}$
$\frac{5}{16}$	$1\frac{9}{32}$	$1\frac{3}{16}$	$\frac{7}{8}$	$\frac{7}{8}$	$1\frac{9}{32}$	.686	$\frac{39}{64}$	$\frac{7}{8}$
$\frac{3}{8}$	$1\frac{11}{16}$	$1\frac{3}{8}$	1	1	$1\frac{11}{16}$	.794	$\frac{45}{64}$	$1\frac{1}{8}$
$\frac{7}{16}$	$1\frac{13}{16}$	$1\frac{9}{16}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$2\frac{5}{32}$	.902	$\frac{51}{64}$	$1\frac{1}{4}$
$\frac{1}{2}$	$2\frac{9}{32}$	$1\frac{13}{16}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$\frac{7}{8}$	1.011	$\frac{57}{64}$	$1\frac{3}{8}$
$\frac{9}{16}$	2	$1\frac{15}{16}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$3\frac{1}{32}$	1.119	$\frac{63}{64}$	$1\frac{1}{2}$
$\frac{5}{8}$	$1\frac{1}{16}$	2	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{1}{16}$	1.227	1 $\frac{5}{64}$	$1\frac{5}{8}$
$\frac{3}{4}$	$1\frac{11}{32}$	$2\frac{3}{16}$	$1\frac{3}{4}$	2	$1\frac{1}{4}$	1.444	1 $\frac{9}{32}$	$1\frac{7}{8}$
$\frac{7}{8}$	$1\frac{9}{16}$	$2\frac{5}{16}$	$1\frac{7}{8}$	$2\frac{1}{4}$	$1\frac{7}{16}$	1.660	$1\frac{15}{32}$	$2\frac{1}{8}$
1	$1\frac{25}{32}$	$2\frac{7}{16}$	$2\frac{1}{8}$	$2\frac{1}{2}$	$1\frac{5}{8}$	1.877	$1\frac{21}{32}$	$2\frac{1}{4}$
$1\frac{1}{8}$	$1\frac{31}{32}$	$3\frac{1}{16}$	$2\frac{3}{8}$	$2\frac{3}{4}$	$1\frac{13}{16}$	2.093	$1\frac{27}{32}$	$2\frac{1}{2}$
$1\frac{1}{4}$	$2\frac{3}{16}$	$4\frac{1}{8}$	$2\frac{1}{2}$	3	2	2.310	2 $\frac{1}{32}$	$2\frac{3}{4}$
$1\frac{3}{8}$	$2\frac{13}{32}$	$4\frac{7}{16}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$2\frac{3}{16}$	2.527	$2\frac{7}{32}$	3
$1\frac{1}{2}$	$2\frac{5}{8}$	$4\frac{13}{16}$	3	$3\frac{1}{2}$	$2\frac{3}{8}$	2.743	$2\frac{13}{32}$	$3\frac{5}{16}$
$1\frac{5}{8}$	$2\frac{13}{16}$	$5\frac{3}{16}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$2\frac{9}{16}$	2.960		
$1\frac{3}{4}$	$3\frac{1}{32}$	$5\frac{9}{16}$	$3\frac{1}{2}$	4	$2\frac{3}{4}$	3.176		
$1\frac{7}{8}$	$3\frac{1}{4}$	$6\frac{1}{32}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$2\frac{15}{16}$	3.393		
2	$3\frac{15}{32}$	$6\frac{7}{16}$	$3\frac{7}{8}$	$4\frac{1}{2}$	3	3.609		
$2\frac{1}{4}$	$3\frac{7}{8}$	$7\frac{7}{8}$	$4\frac{1}{2}$	$4\frac{3}{4}$	$3\frac{1}{8}$	4.043		
$2\frac{1}{2}$	$4\frac{5}{16}$	$7\frac{15}{16}$	5	5	$3\frac{1}{4}$	4.476		
$2\frac{3}{4}$	$4\frac{23}{32}$	$8\frac{1}{16}$	$5\frac{1}{4}$	...	$4\frac{1}{4}$	4.909		
3	$5\frac{5}{32}$	9	$5\frac{3}{4}$	...	$4\frac{3}{8}$	5.342		
$3\frac{1}{4}$	$5\frac{15}{32}$	$10\frac{1}{4}$	$6\frac{1}{4}$	...	5	5.775		
$3\frac{1}{2}$	6	$11\frac{1}{16}$	$6\frac{1}{2}$	...	$5\frac{3}{8}$	6.208		
$3\frac{3}{4}$	$6\frac{13}{32}$	$11\frac{3}{16}$	7	...	$5\frac{3}{4}$	6.641		
4	$6\frac{7}{8}$	$12\frac{9}{16}$	$7\frac{1}{2}$	...	$6\frac{1}{8}$	7.074		
$4\frac{1}{4}$	$7\frac{5}{32}$	13 $\frac{3}{8}$	8	...	$6\frac{1}{2}$	7.508		
$4\frac{1}{2}$	$7\frac{23}{32}$	$14\frac{3}{16}$	$8\frac{1}{2}$	...	$6\frac{7}{8}$	7.941		
$4\frac{3}{4}$	$8\frac{5}{8}$	$14\frac{15}{16}$	$8\frac{3}{4}$	...	$7\frac{1}{4}$	8.374		
5	$8\frac{1}{16}$	$15\frac{3}{4}$	$9\frac{1}{2}$	...	$7\frac{5}{8}$	8.807		
$5\frac{1}{4}$	9	$16\frac{1}{2}$	$9\frac{3}{4}$	...	8	9.240		
$5\frac{1}{2}$	$9\frac{13}{32}$	$17\frac{1}{4}$	$10\frac{1}{4}$	...	$8\frac{3}{8}$	9.673		
$5\frac{3}{4}$	$9\frac{27}{32}$	$18\frac{1}{16}$	$10\frac{3}{4}$	...	$8\frac{3}{4}$	10.106		
6	$10\frac{13}{16}$	$18\frac{15}{16}$	11	...	$9\frac{1}{8}$	10.539		

Hole in washer = diameter of bolt + $\frac{1}{16}$ for bolts up to and including 1 inch in diameter.

Hole in washer = diameter of bolts + $\frac{1}{8}$ inch for bolts $1\frac{1}{8}$ to $2\frac{1}{2}$ inches in diameter, inclusive.

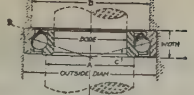
Counterbores with Inserted Pilots



⅝ to 1″ Counterbores to have 4 Flutes
1″ to 1½″ " " 6 "

Diam. A	K	L	M	N	O
⅜	1 7/32	¼	1 15/32	⅜	From 3/16″ to 15/32″ in 32nds.
7/16	"	"	"	1/16	
½	1 27/32	⅜	2 7/32	5/16	
9/16	"	"	"	"	
5/8	"	"	"	"	
11/16	"	"	"	"	
¾	"	"	"	"	From ½″ to 31/32″ in 32nds.
13/16	"	"	"	"	
⅞	"	"	"	"	
15/16	"	"	"	"	
1	"	"	"	"	
1 1/16	2 21/32	½	2 27/32	½	
1 ⅛	"	"	"	"	
1 3/16	"	"	"	"	
1 ¼	"	"	"	"	From 1″ to 1 15/32″ in 32nds.
1 5/16	"	"	"	"	
1 ⅜	"	"	"	"	
1 7/16	"	"	"	"	
1 ½	"	"	"	"	

Diam. A	B	C	D	E	F	G	H	I	J
⅜	3/16	1 1/2	5/16	1	1 1/2	3 1/2	3/16	1 1/16	1 1/4
7/16	"	1 3/32	"	1 3/32	1 5/16	3 11/16	"	1 3/32	"
½	"	1 1/16	"	1 1/16	1 3/8	3 7/8	"	1 1/8	"
9/16	5/16	1 5/32	½	1 1/8	1 1/16	4 1/8	¼	1 5/32	1 7/8
5/8	"	1 7/32	"	1 3/16	¾	4 5/16	"	1 3/16	"
11/16	"	1 5/16	"	1 ¼	1 13/16	4 ½	"	1 7/32	"
¾	"	1 3/8	"	1 5/16	1 7/8	4 11/16	"	1 ¼	"
13/16	"	1 7/16	"	1 3/8	1 15/16	4 15/16	"	1 9/32	"
⅞	"	1 ½	"	1 7/16	2	5 ⅛	"	1 5/16	"
15/16	"	1 9/16	"	1 ½	2 1/16	5 3/8	"	1 3/32	"
1	"	1 5/8	"	1 9/16	2 1/8	5 5/8	"	1 ⅜	"
1 1/16	½	1 11/16	¾	1 5/8	2 3/16	5 13/16	5/16	1 13/32	2 3/8
1 ⅛	"	1 ¾	"	1 11/16	2 ¼	6	"	1 7/16	"
1 3/16	"	1 13/16	"	1 ¾	2 5/16	6 ⅛	"	1 15/32	"
1 ¼	"	1 ⅞	"	1 13/16	2 3/8	6 ¼	"	1 ½	"
1 5/16	"	1 15/16	"	1 ⅞	2 7/16	6 7/16	"	1 17/32	"
1 ⅜	"	2	"	1 15/16	2 ½	6 5/8	"	1 9/16	"
1 7/16	"	2 1/16	"	2	2 9/16	6 ⅞	"	1 19/32	"
1 ½	"				2 5/8	7 5/16	"	1 5/8	"



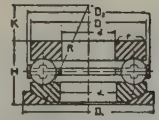
New Departure Ball Bearings—Radax Type
(Combined Radial and One-Direction Thrust Loads)

Bearing No.	Bore Mm.	Bore Inches	Diameter Mm.	Diameter Inches	Width Mm.	Width Inches	Balls Diam.	Balls No.	Chamfer C	Radius R	Shoulder A	Shoulder B	Load 600 R.p.m.
0304	20	0.7874	52	2.0473	15	0.5906	11/32	10	0.040	0.040	1.12	1.81	684
0404			72	2.8347	19	0.7480	9/16	8	0.080	0.080	1.25	2.37	1,495
0305	25	0.9843	62	2.4410	17	0.6693	13/32	11	0.040	0.040	1.31	2.12	995
0405			80	3.1496	21	0.8268	5/8	8	0.080	0.080	1.50	2.69	1,630
0206			62	2.4410	16	0.6299	11/32	13	0.040	0.040	1.50	2.19	777
0306	30	1.1811	72	2.8347	19	0.7480	13/32	11	0.080	0.080	1.62	2.50	1,265
0406			90	3.5433	23	0.9055	11/16	9	0.080	0.080	1.75	3.00	2,245
0207			72	2.8347	17	0.6693	13/32	13	0.040	0.040	1.75	2.50	1,055
0307	35	1.3780	80	3.1496	21	0.8268	13/32	11	0.080	0.080	1.81	2.81	1,570
0407			100	3.9370	25	0.9843	3/4	9	0.080	0.080	2.00	3.37	2,535
0208			80	3.1496	18	0.7087	7/16	14	0.080	0.080	1.94	2.81	1,280
0308	40	1.5748	90	3.5433	23	0.9055	9/16	11	0.080	0.080	2.00	3.12	1,945
0408			110	4.3307	27	1.0630	11/16	9	0.080	0.080	2.19	3.69	2,840
0209	45	1.7717	85	3.3465	19	0.7480	7/16	15	0.080	0.080	2.19	3.00	1,330
0309			100	3.9370	25	0.9843	25/32	12	0.080	0.080	2.31	3.50	2,425
0210	50	1.9685	90	3.5433	20	0.7874	7/16	16	0.080	0.080	2.37	3.25	1,410
0310			110	4.3307	27	1.0630	25/32	12	0.080	0.080	2.50	3.81	2,815
0211	55	2.1654	100	3.9370	21	0.8268	1/2	16	0.080	0.080	2.62	3.56	1,795
0311			120	4.7244	29	1.1417	15/32	12	0.080	0.080	2.75	4.19	3,230
0212	60	2.3622	110	4.3307	22	0.8661	17/32	16	0.080	0.080	2.81	3.87	1,995
0213	65	2.5591	120	4.7244	23	0.9055	9/16	17	0.080	0.080	3.12	4.19	2,350
0214	70	2.7559	125	4.9212	24	0.9448	19/32	17	0.080	0.080	3.25	4.44	2,595
0215	75	2.9528	130	5.1181	25	0.9843	5/8	17	0.080	0.080	3.56	4.62	2,860
0216	80	3.1496	140	5.5118	26	1.0236	11/16	17	0.120	0.120	3.81	5.00	3,395
0217	85	3.3465	150	5.9055	28	1.1024	1/2	16	0.120	0.120	3.94	5.31	3,730
0218	90	3.5433	160	6.2992	30	1.1811	13/16	16	0.120	0.120	4.19	5.69	4,280
0219	95	3.7402	170	6.6929	32	1.2598	1/2	16	0.120	0.120	4.44	6.00	4,830

Figures in the first and last columns, **00** to **22**, indicate the last two digits of bearing numbers. Figures in the headings indicate series. The dimensions for any given size, as No. 1203, are found at the intersection of a column and a row. For the bore, down the "Bore" column to row **03**; answer, 17 millimeters. For the outside diameter, down column 200 to row **03**; answer, 40 millimeters. For the width, down column 1,200 to row **03**; answer, 12 millimeters. For the ball size, down column 1200 to row **03**; answer, $\frac{7}{32}$ inches.

Size	Bore All Series	Outside Diameter in Millimeters			Width in Millimeters								Width over Projecting Balls in Millimeters		Ball Sizes in Inches										Size
		200	300	400	1200 6200	1300 6300	400 6400	5200	5300	5400	2200 22200	2300 22300	1400	1300	1400	6200	6300	6400	5200	5300	5400	1200	1300	400 2200	2300	1400	
00	10	30	35		9	11					14	17				3/16	1/4										00
01	12	32	37		10	12					14	17				3/16	1/4										01
02	15	35	42		11	13					14	17				3/32	1/4					3/16	1/4	3/32	3/32		02
03	17	40	47	62	12	14		17	22.22	30.16	19	19				3/32	5/16				5/16	3/32	3/32	3/32	3/32		03
04	20	47	52	72	14	15	19	19.05	22.22	34.92	18	21				1/4	5/16	1/2			1/2	3/32	3/32	3/32	3/32		04
05	25	52	62	80	15	17	21	19.05	25.40	34.92	18	24	25**		27.6	1/4	3/8	1/2	3/32	1/2	1/2	1/4	3/32	3/32	3/32	1/8	05
06	30	62	72	90	16	19	23	19.05	30.16	39.69	20	27	28**		32.1	5/16	7/16	11/16	3/32	11/16	11/16	5/16	3/32	3/32	3/32	1/8	06
07	35	72	80	100	17	21	25	22.22	34.92	44.45	23	31	30**		33.9	5/16	7/16	11/16	3/32	11/16	11/16	5/16	3/32	3/32	3/32	1/8	07
08	40	80	90	110	18	23	27	25.40	36.51	49.21	23	33	33**		36.8	3/8	1/2	13/16	1/8	13/16	13/16	3/8	1/8	1/8	1/8	1/8	08
09	45	85	100	120	19	25	29	25.40	39.60	53.97	23	36	35**		39.8	7/16	9/16	15/16	1/8	15/16	15/16	7/16	1/8	1/8	1/8	1/8	09
10	50	90	110	130	20	27	31	25.40	44.45	58.74	23	40*	37**		42.8	7/16	5/8	1 1/16	1/8	1 1/16	1 1/16	7/16	1/8	1/8	1/8	1/8	10
11	55	100	120	140	21	29	33	30.16	49.21	63.50	25	43	40**		44.5	1/2	11/16	1 1/8	1/8	1 1/8	1 1/8	1/2	1/8	1/8	1/8	1/8	11
12	60	110	130	150	22	31	35	34.92	53.07	66.67	28	46*	42**		47.5	9/16	13/16	1 1/16	1/8	1 1/16	1 1/16	9/16	1/8	1/8	1/8	1/8	12
13	65	120	140	160	23	33	37	34.92	58.74	71.44	31	48	45**		47.5	9/16	13/16	1 1/16	1/8	1 1/16	1 1/16	9/16	1/8	1/8	1/8	1/8	13
14	70	125	150	180	24	35	42	36.51	63.50	79.37	31	51*	50**		55.1	5/8	7/8	1 5/16	1/8	1 5/16	1 5/16	5/8	1/8	1/8	1/8	1/8	14
15	75	130	160	190	25	37	45	36.51	68.26	82.55	31	55	53**		58.2	11/16	15/16	1 7/16	1/8	1 7/16	1 7/16	11/16	1/8	1/8	1/8	1/8	15
16	80	140	170	200	26	39	48	41.27	68.26	87.31	33*	58*	57**		64.3	3/4	1 1/16	1 1/8	1/8	1 1/8	1 1/8	3/4	1/8	1/8	1/8	1/8	16
17	85	150	180	210	28	41	52	44.45	73.02	92.07	36	60	60**		67.3	13/16	1 1/8	1 1/8	1/8	1 1/8	1 1/8	13/16	1/8	1/8	1/8	1/8	17
18	90	160	190	225	30	43**	54	50.80	73.02	98.42	40*	64*	63**	44.92	70.4	7/8	1 1/8	1 1/8	1/8	1 1/8	1 1/8	7/8	1/8	1/8	1/8	1/8	18
19	95	170	200	250	32	45**	55	55.50	77.79	106.36	43	67	67**	47.90	76.5	15/16	1 3/16	1 3/16	1/8	1 3/16	1 3/16	15/16	1/8	1/8	1/8	1/8	19
20	100	180	215	265	34	47**	60	60.32	82.55	114.30	46*	73*	70**	51.85	82.7	1	1 1/4	1 1/4	1/8	1 1/4	1 1/4	1	1/8	1/8	1/8	1/8	20
21	105	190	225	280†	36	49**		65.00	87.31		50	77	96	53.91		1 1/16	1 5/16	1 5/16	1/8	1 5/16	1 5/16	1 1/16	1/8	1/8	1/8	1/8	21
22	110	200	240	300†	38	50**		69.85	92.07		53*	80*	102	54.94		1 1/8	1 3/8	1 3/8	1/8	1 3/8	1 3/8	1 1/8	1/8	1/8	1/8	1/8	22

* Sizes marked with asterisk are both ball- and roller-bearing sizes; others ball-bearing only.
** These sizes in the 1,300 and 1,400 series have a width over projecting balls. See last two columns of widths.
† Sizes 21 and 22 in 1,400 series only.



500 Series S. K. F.—One-Direction, Spherical-Seat, Extra-Heavy Series

Bearing Number	d		d_1		D		D_1		H		R		D_2		K		r		Ball Dia.	Weight, Pounds
	mm.	in.	mm.	in.	mm.	in.	mm.	in.	mm.	in.	mm.	in.	mm.	in.	mm.	in.	mm.	in.	in.	
502	15	0.5906	17	0.668	35	1.378	44.5	1.752	22	0.865	30	1.181	39	1.535	7.9	0.311	1	0.04	5/16	0.31
503	17	0.6693	19	0.747	37	1.457	44.5	1.752	22	0.865	35	1.378	41	1.614	13.0	0.524	1	0.04	5/16	0.33
504	20	0.7874	22	0.865	45	1.772	50	1.968	26	1.024	40	1.575	48	1.890	13.0	0.512	1	0.04	3/8	0.52
505	25	0.9843	27	1.062	58	2.284	63	2.480	32	1.250	45	1.772	63	2.480	10.0	0.394	1	0.04	3/8	1.07
506	30	1.1811	32	1.259	64	2.520	71	2.795	36	1.417	50	1.969	69	2.717	10.4	0.410	1	0.04	7/16	1.43
507	35	1.3780	37	1.456	72	2.835	79	3.110	41	1.614	60	2.362	77.5	3.051	16.4	0.646	1	0.04	7/16	1.99
508	40	1.5748	42	1.652	85	3.347	95	3.740	47	1.850	70	2.756	91	3.583	19	20.756	1	0.04	1/2	3.22
509	45	1.7717	47	1.849	95	3.740	111	4.370	53	2.087	80	3.140	102	4.016	23.0	0.906	1	0.04	1/2	4.72
510	50	1.9685	52	2.046	110	4.331	127	5.000	59	2.323	90	3.543	115.5	4.547	25.2	0.992	1	0.04	1	7.05
511	55	2.1654	58	2.282	120	4.724	142	5.591	67	2.638	100	3.937	129	5.079	27.2	1.071	1	0.04	1 1/8	10.00
512	60	2.3622	63	2.479	130	5.118	150	5.906	71	2.795	110	4.331	139	5.472	31.7	1.248	1	0.04	1 3/8	11.95
513	65	2.5591	68	2.676	140	5.512	158	6.221	77	3.032	125	4.921	149	5.866	42.0	1.654	1.5	0.06	1 1/4	14.94
514	70	2.7559	73	2.873	150	5.906	180	7.087	84	3.307	140	5.512	161	6.339	50.2	1.976	1.5	0.06	1 3/8	19.93
515	75	2.9528	78	3.070	160	6.299	190	7.480	90	3.543	150	5.906	172.5	6.791	52.7	2.075	1.5	0.06	1 1/2	22.39
516	80	3.1496	83	3.267	170	6.693	200	7.874	94	3.701	155	6.102	182	7.165	52.6	2.071	1.5	0.06	1 9/16	27.28
517	85	3.3465	88	3.464	180	7.087	210	8.268	100	3.937	160	6.299	191	7.520	52.3	2.059	1.5	0.06	1 5/8	32.34
518	90	3.5433	93	3.660	190	7.480	222	8.740	104	4.095	165	6.496	202.5	7.972	52.2	2.055	1.5	0.06	1 11/16	36.65
520	100	3.9370	103	4.054	215	8.465	254	10.000	114	4.489	180	7.087	226	8.898	52.9	2.083	1.5	0.06	2	51.79
523	115	4.5276	118	4.645	240	9.449	275	10.827	125	4.921	200	7.874	253	9.961	60.0	2.362	2	0.08	2 1/4	75.46
525	125	4.9213	128	5.038	270	10.630	310	12.205	135	5.315	230	9.055	284	11.181	78.2	3.079	2	0.08	2 3/8	97.13
528	140	5.5118	143	5.629	300	11.811	340	13.386	145	5.709	260	10.236	315	12.402	94.4	3.717	2	0.08	2 5/8	126.83

When ordering any of the above bearing specify aligning washers separately.
Washers are denoted by the letter U, thus bearing No. 510 and washer No. 510 U.

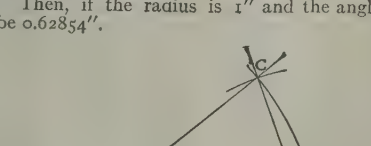
INTEGRAL RIGHT-ANGLED TRIANGLES

THE erection of a perpendicular by the construction of a triangle whose sides are respectively 3, 4 and 5 units in length is a familiar and handy device. The following table gives a greater range of choice in the shape or proportions of the triangle employed. The table is a list of all integral, or whole-number, right-angled triangles the units of whose least sides do not exceed 20.

Height	Base	Hypot-enuse	Height	Base	Hypot-enuse	Height	Base	Hypot-enuse
3	4	5	12	16	20	17	144	145
5	12	13	12	35	37	18	24	30
6	8	10	13	84	85	18	80	82
7	24	25	14	48	50	19	180	181
8	15	17	15	20	25	20	21	29
9	12	15	15	36	39	20	48	52
9	40	41	15	112	113	20	99	101
10	24	26	16	30	34			
11	60	61	16	63	65			

TABLE OF CHORDS

To construct any angle from the table of chords, page 616: Let the required angle be 36° 38′; the nearest angles in the table are 36° 30′ and 36° 40′, and the chords are respectively 0.6263 and 0.6291, the difference 0.0028 corresponding to an angular difference of 10′. To find the amount which must be added to 0.6263 (the chord corresponding to 36° 30′) in order to obtain the chord for a 36° 38′ arc, multiply 0.0028 by $\frac{8}{10}$ = 0.00224. 0.6263 + 0.00224 = 0.62854. Then, if the radius is 1″ and the angle 36° 38′ the chord will be 0.62854″.



In laying out an angle as in the accompanying illustration a base line *A B* can be drawn, say 10 inches long, then with a radius *A B* and center *A*, arc *B C* can be struck. Multiply chord 0.62854 inch by 10 giving 6.2854 inches, as the radius of an arc to be struck from center *B* and cutting arc *B C* at *C*. Through point *C* draw a line *A C* and the angle *B A C* will equal 36° 38′.

Where the angle required is in even degrees or sixths of degrees (as 10′, 20′, etc.) the corresponding chord may be taken directly

Table of Chords

THE TABULATED QUANTITIES = TWICE THE SINE OF HALF THE ARC

Deg.	0′	10′	20′	30′	40′	50′	60′
0	.0000	.0029	.0058	.0087	.0116	.0145	.0174
1	.0174	.0204	.0233	.0262	.0291	.0320	.0349
2	.0349	.0378	.0407	.0436	.0465	.0494	.0523
3	.0523	.0553	.0582	.0611	.0640	.0669	.0698
4	.0698	.0727	.0756	.0785	.0814	.0843	.0872
5	.0872	.0901	.0930	.0959	.0988	.1017	.1047
6	.1047	.1076	.1105	.1134	.1163	.1192	.1221
7	.1221	.1250	.1279	.1308	.1337	.1366	.1395
8	.1395	.1424	.1453	.1482	.1511	.1540	.1569
9	.1569	.1598	.1627	.1656	.1685	.1714	.1743
10	.1743	.1772	.1801	.1830	.1859	.1888	.1917
11	.1917	.1946	.1975	.2004	.2033	.2062	.2090
12	.2090	.2119	.2148	.2177	.2206	.2235	.2264
13	.2264	.2293	.2322	.2351	.2380	.2409	.2437
14	.2437	.2466	.2495	.2524	.2553	.2582	.2610
15	.2610	.2639	.2668	.2697	.2726	.2755	.2783
16	.2783	.2812	.2841	.2870	.2899	.2927	.2956
17	.2956	.2985	.3014	.3042	.3071	.3100	.3129
18	.3129	.3157	.3186	.3215	.3243	.3272	.3301
19	.3301	.3330	.3358	.3387	.3416	.3444	.3473
20	.3473	.3502	.3530	.3559	.3587	.3616	.3645
21	.3645	.3673	.3702	.3730	.3759	.3788	.3816
22	.3816	.3845	.3873	.3902	.3930	.3959	.3987
23	.3987	.4016	.4044	.4073	.4101	.4130	.4158
24	.4158	.4187	.4215	.4243	.4272	.4300	.4329
25	.4329	.4357	.4385	.4414	.4442	.4471	.4499
26	.4499	.4527	.4556	.4584	.4612	.4641	.4669
27	.4669	.4697	.4725	.4754	.4782	.4810	.4838
28	.4838	.4867	.4895	.4923	.4951	.4979	.5008
29	.5008	.5036	.5064	.5092	.5120	.5148	.5176
30	.5176	.5204	.5232	.5261	.5289	.5317	.5345
31	.5345	.5373	.5401	.5429	.5457	.5485	.5513
32	.5513	.5541	.5569	.5596	.5624	.5652	.5680
33	.5680	.5708	.5736	.5764	.5792	.5820	.5847
34	.5847	.5875	.5903	.5931	.5959	.5986	.6014
35	.6014	.6042	.6069	.6097	.6125	.6153	.6180
36	.6180	.6208	.6236	.6263	.6291	.6318	.6346
37	.6346	.6374	.6401	.6429	.6456	.6484	.6511
38	.6511	.6539	.6566	.6594	.6621	.6649	.6676
39	.6676	.6703	.6731	.6758	.6786	.6813	.6840
40	.6840	.6868	.6895	.6922	.6950	.6977	.7004
41	.7004	.7031	.7059	.7086	.7113	.7140	.7167
42	.7167	.7194	.7222	.7249	.7276	.7303	.7330
43	.7330	.7357	.7384	.7411	.7438	.7465	.7492
44	.7492	.7519	.7546	.7573	.7600	.7627	.7654
45	.7654	.7680	.7707	.7734	.7761	.7788	.7815

TABLE OF CHORDS—*Continued*

THE TABULATED QUANTITIES = TWICE THE SINE OF HALF THE ARC

Deg.	0′	10′	20′	30′	40′	50′	60′
46	.7815	.7841	.7868	.7895	.7921	.7948	.7975
47	.7975	.8001	.8028	.8055	.8081	.8108	.8135
48	.8135	.8161	.8188	.8214	.8241	.8267	.8294
49	.8294	.8320	.8347	.8373	.8400	.8426	.8452
50	.8452	.8479	.8505	.8531	.8558	.8584	.8610
51	.8610	.8636	.8663	.8689	.8715	.8741	.8767
52	.8767	.8793	.8820	.8846	.8872	.8898	.8924
53	.8924	.8950	.8976	.9002	.9028	.9054	.9080
54	.9080	.9106	.9132	.9157	.9183	.9209	.9235
55	.9235	.9261	.9286	.9312	.9338	.9364	.9389
56	.9389	.9415	.9441	.9466	.9492	.9518	.9543
57	.9543	.9569	.9594	.9620	.9645	.9671	.9696
58	.9696	.9722	.9747	.9772	.9798	.9823	.9848
59	.9848	.9874	.9899	.9924	.9949	.9975	1.0000
60	1.0000	1.0025	1.0050	1.0075	1.0100	1.0126	1.0151
61	1.0151	1.0176	1.0201	1.0226	1.0251	1.0276	.0301
62	1.0301	1.0326	1.0350	1.0375	1.0400	1.0425	1.0450
63	1.0450	1.0475	1.0500	1.0524	1.0550	1.0574	1.0598
64	1.0598	1.0623	1.0648	1.0672	1.0697	1.0721	1.0746
65	1.0746	1.0770	1.0795	1.0819	1.0844	1.0868	1.0893
66	1.0893	1.0917	1.0941	1.0966	1.0990	1.1014	1.1039
67	1.1039	1.1063	1.1087	1.1111	1.1135	1.1159	1.1184
68	1.1184	1.1208	1.1232	1.1256	1.1280	1.1304	1.1328
69	1.1328	1.1352	1.1376	1.1400	1.1424	1.1448	1.1471
70	1.1471	1.1495	1.1519	1.1543	1.1567	1.1590	1.1614
71	1.1614	1.1638	1.1661	1.1685	1.1708	1.1732	1.1756
72	1.1756	1.1780	1.1803	1.1826	1.1850	1.1873	1.1896
73	1.1896	1.1920	1.1943	1.1966	1.1990	1.2013	1.2036
74	1.2036	1.2059	1.2083	1.2106	1.2129	1.2152	1.2175
75	1.2175	1.2198	1.2221	1.2244	1.2267	1.2290	1.2313
76	1.2313	1.2336	1.2360	1.2382	1.2405	1.2427	1.2450
77	1.2450	1.2473	1.2496	1.2518	1.2541	1.2564	1.2586
78	1.2586	1.2609	1.2631	1.2654	1.2677	1.2699	1.2721
79	1.2721	1.2744	1.2766	1.2789	1.2811	1.2833	1.2856
80	1.2856	1.2878	1.2900	1.2922	1.2945	1.2967	1.2989
81	1.2989	1.3011	1.3033	1.3055	1.3077	1.3099	1.3121
82	1.3121	1.3143	1.3165	1.3187	1.3209	1.3231	1.3252
83	1.3252	1.3274	1.3296	1.3318	1.3340	1.3361	1.3383
84	1.3383	1.3404	1.3426	1.3447	1.3469	1.3490	1.3512
85	1.3512	1.3533	1.3555	1.3576	1.3597	1.3619	1.3640
86	1.3640	1.3661	1.3682	1.3704	1.3725	1.3746	1.3767
87	1.3767	1.3788	1.3809	1.3830	1.3851	1.3872	1.3893
88	1.3893	1.3914	1.3935	1.3956	1.3977	1.3997	1.4018
89	1.4018	1.4039	1.4060	1.4080	1.4101	1.4121	1.4142
90	1.4142						

TABLE FOR SPACING HOLES IN CIRCLES

No. of Divisions in Circle	Deg. of Arc	Length of Chord Dia. 1	Length of Chord Dia. 2	Length of Chord Dia. 3	Length of Chord Dia. 4	Length of Chord Dia. 5	Length of Chord Dia. 6
3	120	.866	1.732	2.598	3.464	4.330	5.196
4	90	.707	1.414	2.121	2.828	3.536	4.243
5	72	.588	1.176	1.763	2.351	2.938	3.527
6	60	.500	1.000	1.500	2.000	2.500	3.000
7	51°–25′	.434	.868	1.302	1.736	2.170	2.604
8	45	.383	.765	1.148	1.531	1.913	2.296
9	40	.342	.684	1.026	1.368	1.710	2.052
10	36	.309	.618	.927	1.236	1.545	1.854
11	32°–43′	.282	.564	.845	1.127	1.409	1.691
12	30	.259	.518	.776	1.035	1.294	1.553
13	27°–41′	.239	.479	.718	.958	1.197	1.436
14	25°–42′	.222	.445	.667	.890	1.112	1.334
15	24	.208	.416	.624	.832	1.040	1.247
16	22°–30′	.195	.390	.585	.780	.975	1.171
17	21°–11′	.184	.367	.551	.735	.918	1.102
18	20	.174	.347	.521	.695	.868	1.041
19	18°–57′	.164	.329	.493	.658	.822	.987
20	18	.156	.318	.469	.626	.782	.937
21	17°– 8′	.149	.298	.447	.596	.745	.894
22	16°–22′	.142	.286	.427	.569	.712	.855
23	15°–39′	.136	.273	.409	.545	.681	.818
24	15	.130	.261	.392	.522	.653	.783
25	14°–24′	.125	.251	.375	.501	.627	.752
26	13°–51′	.120	.241	.361	.482	.602	.723
27	13°–20′	.116	.232	.348	.464	.580	.697
28	12°–51′	.112	.224	.336	.448	.560	.672
29	12°–25′	.108	.216	.324	.432	.540	.648
30	12	.104	.209	.314	.418	.522	.627
31	11°–37′	.101	.202	.303	.404	.505	.606
32	11°–15′	.098	.196	.294	.393	.491	.589

TABLE FOR SPACING HOLES IN CIRCLES—*Continued*

No. of Divisions in Circle	Deg. of Arc	Length of Chord Dia. 7	Length of Chord Dia. 8	Length of Chord Dia. 9	Length of Chord Dia. 10	Length of Chord Dia. 11	Length of Chord Dia. 12
3	120	6.062	6.928	7.794	8.660	9.526	10.392
4	90	4.950	5.657	6.364	7.071	7.778	8.485
5	72	4.115	4.702	5.290	5.878	6.465	7.053
6	60	3.500	4.000	4.500	5.000	5.500	6.000
7	51°–25′	3.037	3.471	3.905	4.339	4.773	5.207
8	45	2.679	3.061	3.444	3.827	4.210	4.592
9	40	2.394	2.736	3.078	3.420	3.762	4.104
10	36	2.163	2.472	2.781	3.090	3.399	3.708
11	32°–43′	1.973	2.254	2.536	2.818	3.100	3.381
12	30	1.812	2.069	2.329	2.588	2.847	3.106
13	27°–41′	1.676	1.915	2.154	2.394	2.633	2.873
14	25°–42′	1.557	1.779	2.000	2.224	2.446	2.669
15	24	1.455	1.663	1.871	2.079	2.287	2.495
16	22°–30′	1.366	1.561	1.756	1.951	2.146	2.341
17	21°–11′	1.286	1.469	1.653	1.837	2.020	2.204
18	20	1.216	1.389	1.563	1.737	1.910	2.084
19	18°–57′	1.151	1.316	1.480	1.645	1.809	1.974
20	18	1.095	1.251	1.408	1.564	1.721	1.877
21	17°– 8′	1.043	1.192	1.341	1.489	1.639	1.788
22	16°–22′	.996	1.139	1.281	1.423	1.566	1.708
23	15°–39′	.954	1.092	1.227	1.363	1.499	1.635
24	15	.914	1.044	1.175	1.305	1.436	1.566
25	14°–24′	.877	1.003	1.128	1.253	1.379	1.504
26	13°–51′	.843	.963	1.084	1.204	1.325	1.445
27	13°–20′	.813	.929	1.045	1.161	1.277	1.393
28	12°–51′	.784	.896	1.008	1.121	1.233	1.345
29	12°–25′	.756	.864	.972	1.080	1.188	1.296
30	12	.732	.836	.941	1.045	1.150	1.254
31	11°–37′	.707	.808	.910	1.011	1.112	1.213
32	11°–15′	.687	.785	.883	.982	1.080	1.178

from the table. A 10 to 1 layout is particularly convenient as the multiplication of the tabulated chords by 10 is readily performed mentally.

TABLE FOR SPACING HOLES IN CIRCLES

THE table on pages 618 and 619 will be found of service when it is desired to space any number of holes up to and including 32, in a circle. The number of divisions or holes desired will be found in the first column, the corresponding angle included at the center being given as a convenience in the second column. The remaining column heads cover various diameters of circles from 1 to 12 inches, and under these different heads and opposite the required number of holes will be found the lengths of chords or distances between hole centers for the given circle diameter.

Thus, if it is required to space off 18 holes in an 8-inch circle, by following down the first column until 18 is reached and then reading directly to the right, in the column headed "Length of Chord-Dia. 8," will be found the distance 1.389 as the chord length for that number of divisions and diameter of circle. Or, suppose a circle of 12 inches diameter is to be spaced off for a series of 27 holes to be drilled at equal distances apart: Opposite 27 found in the first column, and under the heading, "Dia. 12," will be found the chord 1.393 as the length to which the dividers may be set directly for laying off the series of holes.

If it is desired to lay off a series of holes in a circle of some diameter not given in the table, say 10 holes in an 11½-inch circle, subtract the chord for 10 holes in an 11-inch circle, or, 3.399 from the chord in the "Dia. 12" column, or 3.708, and add half the difference (.154) to 3.399, giving 3.553 as the chord or center distance between holes. Or, if 24 holes are to be equally spaced in a 20-inch circle, all that is necessary in order to find the chord, or center distance, is to find opposite 24, and in the column headed, "Dia. 10," the quantity 1.305 and multiply this by 2, giving a length of 2.610 nches as the center distance.

TABLE OF SIDES, ANGLES AND SINES

THE table on pages 621 to 625 is carried out for a much higher number of sides or spaces than are included in the preceding table and will be found useful in many cases not covered by that table. It was originally computed for finding the thicknesses of commutator bars and also for calculating the chord for spacing slots in armature punchings. In using this table the diameter of the circle is, of course, multiplied by the sine opposite the desired number of holes or sides.

Assuming for illustration that a series of 51 holes are to be equally spaced about a circle having a diameter of 17 inches, opposite 51 in the column headed "No. of Sides," find the quantity .06156 in the column headed "Sine," and multiply this quantity by 17. The product 1.0465 is the length of the chord or the required distance between centers of the holes for this circle. Or, if 40 equidistant points are to be spaced about a circle 16 inches diameter, opposite the number of sides, 40, will be found the quantity .078459 which multiplied by 16 gives 1.255 inch as the distance between centers.

MULTIPLY DIAMETER BY SINE TO GET LENGTH OF SIDE
(Angle given is half of angle subtended at center)

No. Sides	Angle Deg. Min. Sec.	Sine	No. Sides	Angle Deg. Min. Sec.	Sine
3	60	.8660254	52	3–27–41.53	.0603784
4	45	.7071067	53	3–23–46.41	.0592405
5	36	.5877852	54	3–20	.0581448
6	30	.5000000	55	3–16–21.81	.0570887
7	25–42–51.42	.4338828	56	3–12–51.42	.0560704
8	22–30	.3826834	57	3– 9–28.42	.0550877
9	20–	.3420201	58	3– 6–12.41	.0541388
10	18–	.3090170	59	3– 3– 3.05	.0532221
11	16–21–49.09	.2817325	60	3–	.0523360
12	15–	.2588190	61	2–57– 2.95	.0514787
13	13–50–46.15	.2393157	62	2–54–11.61	.0506491
14	12–51–25.71	.2225208	63	2–51–25.71	.0498458
15	12	.2079116	64	2–48– 45	.0490676
16	11–15	.1950903	65	2–46– 9.23	.0483133
17	10–35–17.64	.1837495	66	2–43–38.18	.0475819
18	10–	.1736481	67	2–41–11.64	.0468722
19	9–28–25.26	.1645945	68	2–38–49.41	.0461834
20	9–	.1564344	69	2–36–31.30	.0455145
21	8–34–17.14	.1490422	70	2–34–17.14	.0448648
22	8–10–54.54	.1423148	71	2–32– 6.76	.0442333
23	7–49–33.91	.1361666	72	2–30	.0436194
24	7–30–	.1305262	73	2–27–56.71	.0430222
25	7–12–	.1253332	74	2–25–56.75	.0424411
26	6–55–23.07	.1205366	75	2–24–	.0418757
27	6–40	.1160929	76	2–22– 6.31	.0413249
28	6–25–42.85	.1119644	77	2–20–15.58	.0407885
29	6–12–24.82	.1081189	78	2–18–27.69	.0402659
30	6–	.1045284	79	2–16–42.53	.0397565
31	5–48–23.22	.1011683	80	2–15–	.0392598
32	5–37–30	.0980171	81	2–13–20	.0387753
33	5–27–16.36	.0950560	82	2–11–42.45	.0383027
34	5–17–38.82	.0922683	83	2–10– 7.22	.0378414
35	5– 8–34.28	.0896392	84	2– 8–34.28	.0373911
36	5–	.0871557	85	2– 7– 3.54	.0369515
37	4–51–53.51	.0848058	86	2– 5–34.88	.0365220
38	4–44–12.63	.0825793	87	2– 4– 8.27	.0361023
39	4–36–55.38	.0804665	88	2– 2–43.63	.0356923
40	4–30–	.0784591	89	2– 1–20.89	.0352914
41	4–23–24.87	.0765492	90	2–	.0348995
42	4–17– 8.57	.0747301	91	1–58–40.87	.0345160
43	4–11– 9.76	.0729952	92	1–57–23.47	.0341410
44	4– 5–27.27	.0713391	93	1–56– 7.74	.0337741
45	4	.0697565	94	1–54–53.61	.0334149
46	3–54–46.95	.0682423	95	1–53–41.05	.0330633
47	3–49–47.23	.0667926	96	1–52–30.	.0327190
48	3–45–	.0654031	97	1–51–20.41	.0323818
49	3–40–24.49	.0640702	98	1–50–12.24	.0320515
50	3–36–	.0627905	99	1–49– 5.45	.0317279
51	3–31–45.88	.0615609	100	1–48–	.0314107

MULTIPLY DIAMETER BY SINE TO GET LENGTH OF SIDE
(Angle given is half of angle subtended at center)

No. Sides	Angle Deg. Min. Sec.	Sine	No. Sides	Angle Deg. Min. Sec.	Sine
101	1-46-55.84	.0310098	151	1-11-31.39	.0208037
102	1-45-52.94	.0307950	152	1-11- 3.15	.0206668
103	1-44-51.26	.0304961	153	1-10-35.29	.0205318
104	1-43-50.76	.0302029	154	1-10- 7.79	.0203985
105	1-42-51.42	.0299154	155	1- 9-40.64	.0202669
106	1-41-53.20	.0296332	156	1- 9-13.84	.0201370
107	1-40-56.07	.0293564	157	1- 8-47.38	.0200087
108	1-40-	.0290847	158	1- 8-21.26	.0198821
109	1-39- 4.95	.0288179	159	1- 7-55.47	.0197571
110	1-38-10.90	.0285560	160	1- 7-30	.0196336
111	1-37-17.83	.0282488	161	1- 7- 4.84	.0195117
112	1-36-25.71	.0280462	162	1- 6-40	.0193913
113	1-35-34.51	.0277981	163	1- 6-15.46	.0192723
114	1-34-44.21	.0275543	164	1- 5-51.21	.0191548
115	1-33-54.78	.0273147	165	1- 5-27.27	.0190387
116	1-33- 6.20	.0270793	166	1- 5- 3.61	.0189241
117	1-32-18.46	.0268479	167	1- 4-40.23	.0188107
118	1-31-31.52	.0266204	168	1- 4-17.14	.0186988
119	1-30-45.38	.0263968	169	1- 3-54.31	.0185881
120	1-30-	.0261769	170	1- 3-31.76	.0184788
121	1-29-15.37	.0259606	171	1- 3- 9.47	.0183708
122	1-28-31.47	.0257478	172	1- 2-47.44	.0182640
123	1-27-48.29	.0255386	173	1- 2-25.66	.0181584
124	1-27- 5.80	.0253326	174	1- 2- 4.13	.0180541
125	1-26-24	.0251300	175	1- 1-42.85	.0179509
126	1-25-42.85	.0249306	176	1- 1-21.81	.0178489
127	1-25- 2.36	.0247344	177	1- 1- 1.01	.0177481
128	1-24-22.50	.0245412	178	1- 0-40.44	.0176484
129	1-23-43.25	.0243509	179	1- 0-20.11	.0175498
130	1-23- 4.61	.0241637	180	1- -	.0174524
131	1-22-26.56	.0239793	181	-59-40.11	.0173559
132	1-21-49.09	.0237976	182	-59-20.43	.0172605
133	1-21-12.18	.0236188	183	-59- 0.98	.0171663
134	1-20-35.82	.0234425	184	-58-41.73	.0170730
135	1-20-	.0232689	185	-58-22.70	.0169807
136	1-19-24.70	.0230978	186	-58- 3.87	.0168894
137	1-18-49.92	.0229292	187	-57-45.24	.0167991
138	1-18-15.65	.0227631	188	-57-26.30	.0167097
139	1-17-41.87	.0225994	189	-57- 8.57	.0166214
140	1-17- 8.57	.0224380	190	-56-50.52	.0165339
141	1-16-35.74	.0222789	191	-56-32.67	.0164473
142	1-16- 3.38	.0221220	192	-56-15	.0163617
143	1-15-31.46	.0219673	193	-55-57.51	.0162769
144	1-15-	.0218148	194	-55-40.20	.0161930
145	1-14-28.96	.0216644	195	-55-23.07	.0161100
146	1-13-58.35	.0215160	196	-55- 6.12	.0160278
147	1-13-28.16	.0213697	197	-54-49.34	.0159464
148	1-12-58.37	.0212253	198	-54-32.72	.0158659
149	1-12-28.99	.0210829	199	-54-16.28	.0157862
150	1-12-	.0209424	200	-54-	.0157073

MULTIPLY DIAMETER BY SINE TO GET LENGTH OF SIDE
(Angle given is half of angle subtended at center)

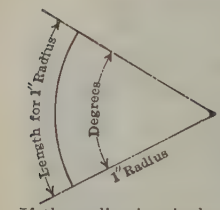
No. Sides	Angle Min. Sec.	Sine	No. Sides	Angle Min. Sec.	Sine
201	53–43.88	.0156244	251	43– 1.67	.0125160
202	53–27.92	.0155518	252	42–51.43	.0124663
203	53–12.12	.0154752	253	42–41.26	.0124171
204	52–56.47	.0153993	254	42–31.18	.0123682
205	52–40.97	.0153242	255	42–21.18	.0123197
206	52–25.63	.0152498	256	42–11.25	.0122715
207	52–10.44	.0151764	257	42– 1.40	.0122238
208	51–55.38	.0151033	258	41–51.63	.0121764
209	51–40.48	.0150310	259	41–41.93	.0121294
210	51–25.71	.0149595	260	41–32.31	.0120827
211	51–11.09	.0148886	261	41–22.76	.0120364
212	50–56.60	.0148183	262	41–13.28	.0119905
213	50–42.25	.0147487	263	41– 3.88	.0119449
214	50–28.04	.0146798	264	40–54.54	.0118997
215	50–13.96	.0146115	265	40–45.28	.0118548
216	50–	.0145439	266	40–36.09	.0118102
217	49–46.17	.0144769	267	40–26.96	.0117660
218	49–32.48	.0144104	268	40–17.91	.0117221
219	49–18.91	.0143446	269	40– 8.93	.0116786
220	49– 5.46	.0142794	270	40–	.0116353
221	48–52.13	.0142148	271	39–51.14	.0115923
222	48–38.92	.0141508	272	39–42.35	.0115497
223	48–25.83	.0140874	273	39–33.63	.0115074
224	48–12.86	.0140245	274	39–24.96	.0114654
225	48–	.0139622	275	39–16.36	.0114237
226	47–47.26	.0139004	276	39– 7.83	.0113823
227	47–34.63	.0138392	277	38–59.35	.0113412
228	47–22.11	.0137785	278	38–50.94	.0113004
229	47– 9.69	.0137183	279	38–42.58	.0112599
230	46–57.39	.0136587	280	38–34.28	.0112197
231	46–45.19	.0135995	281	38–26.05	.0111798
232	46–33.10	.0135409	282	38–17.87	.0111401
233	46–21.11	.0134828	283	38– 9.75	.0111008
234	46– 9.23	.0134252	284	38– 1.69	.0110617
235	45–57.45	.0133681	285	37–53.68	.0110229
236	45–45.76	.0133115	286	17–45.73	.0109844
237	45–34.18	.0132553	287	37–37.84	.0109461
238	45–22.69	.0131996	288	37–30	.0109081
239	45–11.29	.0131444	289	37–22.21	.0108704
240	45–	.0130896	290	37–14.48	.0108329
241	44–48.80	.0130353	291	37– 6.80	.0107957
242	44–37.68	.0129814	292	36–59.18	.0107587
243	44–26.67	.0129280	293	36–51.60	.0107220
244	44–15.74	.0128750	294	36–44.08	.0106855
245	44– 4.90	.0128225	295	36–36.61	.0106493
246	43–54.15	.0127704	296	36–29.19	.0106133
247	43–43.48	.0127187	297	36–21.82	.0105776
248	43–32.40	.0126674	298	36–14.50	.0105421
249	43–22.41	.0126165	299	36– 7.22	.0105068
250	43–12	.0125661	300	36–	.0104718

MULTIPLY DIAMETER BY SINE TO GET LENGTH OF SIDE
(Angle given is half of angle subtended at center)

No. Sides	Angle Min. Sec.	Sine	No. Sides	Angle Min. Sec.	Sine
301	35–52.82	.0104370	351	30–46.15	.0089502
302	35–45.69	.0104024	352	30–40.91	.0089248
303	35–38.61	.0103681	353	30–35.69	.0088996
304	35–31.58	.0103340	354	30–30.51	.0088744
305	35–24.59	.0103001	355	30–25.35	.0088494
306	35–17.65	.0102665	356	30–20.22	.0088245
307	35–10.75	.0102330	357	30–15.12	.0087998
308	35– 3.90	.0101998	358	30–10.05	.0087753
309	34–57.09	.0101668	359	30– 5.01	.0087508
310	34–50.32	.0101340	360	30–	.0087265
311	34–43.60	.0101014	361	29–55.01	.0087023
312	34–36.92	.0100690	362	29–50.05	.0086783
313	34–30.29	.0100368	363	29–45.12	.0086544
314	34–23.69	.0100049	364	29–40.22	.0086306
315	34–17.14	.0099731	365	29–35.34	.0086070
316	34–10.63	.0099415	366	29–30.49	.0085835
317	34– 4.16	.0099102	367	29–25.67	.0085601
318	33–57.74	.0098791	368	29–20.87	.0085368
319	33–51.35	.0098482	369	29–16.10	.0085137
320	33–45	.0098174	370	29–11.35	.0084907
321	33–38.69	.0097868	371	29– 6.63	.0084678
322	33–32.42	.0097564	372	29– 1.94	.0084451
323	33–26.19	.0097261	373	28–57.27	.0084224
324	33–20	.0096961	374	28–52.62	.0083999
325	33–13.85	.0096663	375	28–48	.0083775
326	33– 7.73	.0096367	376	28–43.40	.0083552
327	33– 1.65	.0096072	377	28–38.83	.0083331
328	32–55.61	.0095779	378	28–34.28	.0083110
329	32–49.60	.0095488	379	28–29.76	.0082891
330	32–43.64	.0095198	380	28–25.26	.0082673
331	32–37.70	.0094911	381	28–20.78	.0082456
332	32–31.81	.0094625	382	28–16.33	.0082240
333	32–25.95	.0094341	383	28–11.91	.0082025
334	32–20.12	.0094059	384	28– 7.50	.0081812
335	32–14.33	.0093778	385	28– 3.12	.0081599
336	32– 8.57	.0093499	386	27–58.76	.0081387
337	32– 2.85	.0093221	387	27–54.42	.0081177
338	31–57.16	.0092945	388	27–50.10	.0080968
339	31–51.50	.0092671	389	27–45.81	.0080760
340	31–45.88	.0092398	390	27–41.54	.0080553
341	31–40.29	.0092127	391	27–37.29	.0080347
342	31–34.74	.0091858	392	27–33.06	.0080142
343	31–29.21	.0091590	393	27–28.85	.0079938
344	31–23.72	.0091324	394	27–24.67	.0079735
345	31–18.26	.0091059	395	27–20.51	.0079533
346	31–12.83	.0090796	396	27–16.36	.0079332
347	31– 7.44	.0090534	397	27–12.24	.0079132
348	31– 2.07	.0090274	398	27– 8.14	.0078934
349	30–56.73	.0090016	399	27– 4.06	.0078736
350	30–51.43	.0089758	400	27–	.0078534

MULTIPLY DIAMETER BY SINE TO GET LENGTH OF SIDE
(Angle given is half of angle subtended at center)

No. Sides	Angle Min. Sec.	Sine	No. Sides	Angle Min. Sec.	Sine
401	26–55.96	.0078343	451	23–56.81	.0069658
402	26–51.94	.0078148	452	23–53.63	.0069504
403	26–47.94	.0077954	453	23–50.46	.0069351
404	26–43.96	.0077761	454	23–47.31	.0069198
405	26–40	.0077569	455	23–44.17	.0069046
406	26–36.06	.0077378	456	23–41.05	.0068894
407	26–32.14	.0077188	457	23–37.94	.0068744
408	26–28.23	.0076999	458	23–34.84	.0068594
409	26–24.35	.0076811	459	23–31.76	.0068444
410	26–20.49	.0076623	460	23–28.69	.0068295
411	26–16.64	.0076437	461	23–25.64	.0068147
412	26–12.82	.0076251	462	23–22.60	.0067999
413	26– 9.01	.0076067	463	23–19.57	.0067852
414	26– 5.22	.0075883	464	23–16.55	.0067706
415	26– 1.45	.0075700	465	23–13.55	.0067561
416	25–57.70	.0075518	466	23–10.56	.0067416
417	25–53.96	.0075337	467	23– 7.58	.0067272
418	25–50.24	.0075157	468	23– 4.61	.0067128
419	25–46.54	.0074977	469	23– 1.66	.0066985
420	25–42.86	.0074799	470	22–58.72	.0066842
421	25–39.19	.0074621	471	22–55.79	.0066700
422	25–35.54	.0074444	472	22–52.88	.0066559
423	25–31.91	.0074268	473	22–49.98	.0066418
424	25–28.30	.0074093	474	22–47.09	.0066278
425	25–24.70	.0073919	475	22–44.21	.0066138
426	25–21.12	.0073745	476	22–41.34	.0065999
427	25–17.56	.0073573	477	22–38.49	.0065861
428	25–14.02	.0073401	478	22–35.65	.0065723
429	25–10.49	.0073230	479	22–32.82	.0065585
430	25– 6.98	.0073059	480	22–30	.0065449
431	25– 3.48	.0072890	481	22–27.20	.0065313
432	25–	.0072721	482	22–24.40	.0065178
433	24–56.54	.0072553	483	22–21.61	.0065043
434	24–53.09	.0072386	484	22–18.84	.0064909
435	24–49.66	.0072220	485	22–16.08	.0064775
436	24–46.24	.0072054	486	22–13.33	.0064641
437	24–42.84	.0071889	487	22–10.59	.0064509
438	24–39.45	.0071725	488	22– 7.87	.0064377
439	24–36.08	.0071562	489	22– 5.16	.0064245
440	24–32.73	.0071399	490	22– 2.45	.0064114
441	24–29.39	.0071237	491	21–59.75	.0063983
442	24–26.06	.0071076	492	21–57.07	.0063853
443	24–22.75	.0070916	493	21–54.40	.0063723
444	24–19.46	.0070756	494	21–51.74	.0063594
445	24–16.18	.0070597	495	21–49.09	.0063466
446	24–12.91	.0070439	496	21–46.45	.0063338
447	24– 9.66	.0070281	497	21–43.82	.0063211
448	24– 6.43	.0070124	498	21–41.20	.0063084
449	24– 3.21	.0069968	499	21–38.59	.0062957
450	24–	.0069813	500	21–36	.0062831



LENGTHS OF CIRCULAR ARCS

THE table gives the lengths of circular arcs to the radius of one, for angles from 1 to 180 degrees. The lengths for minutes of arcs are given at the right.

To find the length of a circular arc with radius of 1 inch and angle of 45 degrees 20 minutes. Opposite 45 degrees find 0.7854, and opposite 20 minutes 0.0058. Adding these gives 0.7912 inch as the length of arc. If the radius is 2 inches, multiply the lengths in the table by 2.

LENGTHS OF CIRCULAR ARCS TO RADIUS OF 1

Degree	Length	Degree	Length	Degree	Length	Degree	Length	Min.	Length	Min.	Length
0	0.0000	45	0.7854	90	1.5708	135	2.3562	0	0.0000	45	0.0131
1	0.0175	46	0.8029	91	1.5882	136	2.3736	1	0.0003	46	0.0134
2	0.0349	47	0.8203	92	1.6057	137	2.3911	2	0.0006	47	0.0137
3	0.0524	48	0.8378	93	1.6232	138	2.4086	3	0.0009	48	0.0140
4	0.0698	49	0.8552	94	1.6406	139	2.4260	4	0.0012	49	0.0143
5	0.0873	50	0.8728	95	1.6581	140	2.4435	5	0.0015	50	0.0145
6	0.1047	51	0.8901	96	1.6755	141	2.4609	6	0.0017	51	0.0148
7	0.1222	52	0.9076	97	1.6930	142	2.4784	7	0.0020	52	0.0151
8	0.1396	53	0.9250	98	1.7104	143	2.4958	8	0.0023	53	0.0154
9	0.1571	54	0.9425	99	1.7279	144	2.5133	9	0.0026	54	0.0157
10	0.1745	55	0.9599	100	1.7453	145	2.5307	10	0.0029	55	0.0160
11	0.1920	56	0.9774	101	1.7628	146	2.5482	11	0.0032	56	0.0163
12	0.2094	57	0.9948	102	1.7802	147	2.5656	12	0.0035	57	0.0166
13	0.2269	58	1.0123	103	1.7977	148	2.5831	13	0.0038	58	0.0169
14	0.2443	59	1.0297	104	1.8151	149	2.6005	14	0.0041	59	0.0172
15	0.2618	60	1.0472	105	1.8326	150	2.6180	15	0.0044	60	0.0175
16	0.2793	61	1.0647	106	1.8500	151	2.6354	16	0.0047		
17	0.2967	62	1.0821	107	1.8675	152	2.6529	17	0.0050		
18	0.3142	63	1.0996	108	1.8850	153	2.6704	18	0.0052		
19	0.3316	64	1.1170	109	1.9024	154	2.6878	19	0.0055		
20	0.3491	65	1.1345	110	1.9199	155	2.7052	20	0.0058		
21	0.3665	66	1.1519	111	1.9373	156	2.7227	21	0.0061		
22	0.3840	67	1.1694	112	1.9548	157	2.7402	22	0.0064		
23	0.4014	68	1.1868	113	1.9722	158	2.7576	23	0.0067		
24	0.4189	69	1.2043	114	1.9897	159	2.7751	24	0.0070		
25	0.4363	70	1.2217	115	2.0071	160	2.7925	25	0.0073		
26	0.4538	71	1.2392	116	2.0246	161	2.8100	26	0.0076		
27	0.4712	72	1.2566	117	2.0420	162	2.8274	27	0.0079		
28	0.4887	73	1.2741	118	2.0595	163	2.8449	28	0.0081		
29	0.5061	74	1.2915	119	2.0769	164	2.8623	29	0.0084		
30	0.5236	75	1.3090	120	2.0944	165	2.8798	30	0.0087		
31	0.5411	76	1.3265	121	2.1118	166	2.8972	31	0.0090		
32	0.5585	77	1.3439	122	2.1293	167	2.9147	32	0.0093		
33	0.5760	78	1.3614	123	2.1468	168	2.9322	33	0.0096		
34	0.5934	79	1.3788	124	2.1642	169	2.9496	34	0.0099		
35	0.6109	80	1.3963	125	2.1817	170	2.9671	35	0.0102		
36	0.6283	81	1.4137	126	2.1991	171	2.9845	36	0.0105		
37	0.6458	82	1.4312	127	2.2166	172	3.0020	37	0.0108		
38	0.6632	83	1.4486	128	2.2340	173	3.0194	38	0.0111		
39	0.6807	84	1.4661	129	2.2515	174	3.0369	39	0.0113		
40	0.6981	85	1.4835	130	2.2690	175	3.0543	40	0.0116		
41	0.7156	86	1.5010	131	2.2864	176	3.0718	41	0.0119		
42	0.7330	87	1.5184	132	2.3038	177	3.0892	42	0.0122		
43	0.7505	88	1.5359	133	2.3132	178	3.1067	43	0.0125		
44	0.7679	89	1.5533	134	2.3387	179	3.1241	44	0.0128		

ACTUAL CUTTING SPEED OF PLANERS IN FEET PER MINUTE

Forward Cutting Speed in Feet per Minute	Return Speed						
	2 to 1	3 to 1	4 to 1	5 to 1	6 to 1	7 to 1	8 to 1
20	13.3	15.	16	16.66	17.14	17.5	17.76
25	16.6	18.75	20	20.83	21.42	21.87	22.16
30	20.	22.5	24	25.	25.71	26.25	26.56
35	23.3	26.25	28	29.16	30.	30.62	31.04
40	26.6	30.	32	33.33	34.28	35.	35.52
45	30.	33.75	36	37 5	38.56	39.37	40.
50	33.3	37.5	40	41.66	42.84	43.75	44.48
55	36.6	41.25	44	45.83	47.12	48.12	48.95
60	40.	45.	48	50.	51.42	52.50	53.43
65	43.3	48.75	52	54.16	55.70	56.87	57.91
70	46.6	52.5	56	58.33	60.	61.25	62.3
75	50.	56.25	60	62.5,	64.28	66.62	66.71

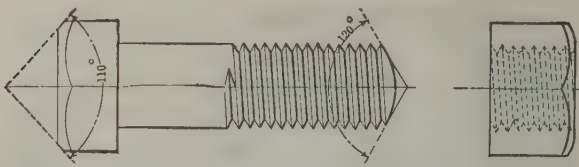
The table shows clearly that a slight increase in cutting speed is better than high return speed. A 25-foot forward speed at 4 to 1 return is much better than 8 to 1 return with 20-feet forward speed. Economical planer speeds are given below (Cincinnati Planer Co.).

Cast Iron roughing . . . 40 to 50 ft.; finishing . . . 20 to 25 ft.
Steel casting and wrought iron roughing 30 to 35 ft.; finishing 20 ft.
Bronze and brass . . . 50 to 60 ft.; Machinery steel . . . 30 to 35 ft.

ALLOWANCES FOR BOLT HEADS AND UPSETS

STOCK ALLOWED FOR STANDARD UPSETS BY ACME MACHINERY CO.

½ in.	Upset to	"	⅝ in.	Length of Upset,	"	3 in.	Stock required,	1⅜ in.
⅝	"	"	¾	"	"	3½	"	1⅝ "
¾	"	"	⅞	"	"	3½	"	1½ "
⅞	"	"	1	"	"	4	"	2⅛ "
1	"	"	1⅛	"	"	4	"	2¼ "
1⅛	"	"	1¼	"	"	4½	"	2⅜ "
1¼	"	"	1⅜	"	"	4½	"	2½ "
1⅜	"	"	1½	"	"	5	"	2⅝ "
1½	"	"	1⅝	"	"	5	"	2¾ "
1⅝	"	"	1¾	"	"	5	"	2 "
1¾	"	"	1⅞	"	"	5½	"	2⅛ "
1⅞	"	"	2	"	"	5½	"	1¾ "
2	"	"	2⅛	"	"	6	"	2 "
2	"	"	2¼	"	"	6	"	2¼ "
2¼	"	"	2⅜	"	"	6	"	3½ "
2½	"	"	2½	"	"	6½	"	2⅜ "
2¾	"	"	2⅝	"	"	6½	"	2½ "
3	"	"	3½	"	"	7	"	2 "
			3½	"	"	7	"	2⅝ "



STOCK REQUIRED TO MAKE AMERICAN STANDARD BOLT HEADS AND NUTS—ROUGH

NATIONAL MACHINERY CO.

Bolt Heads Square or Hexagon					Nuts Square or Hexagon				
Size of Bolt	Short Diameter	Thickness	Stock Required for Upset		Short Diameter	Diameter Hole	Thickness	Size Stock Required Square or Hexagon	
			Square	Hexagon				Width	Thickness
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$1\frac{9}{32}$	$1\frac{7}{32}$	$\frac{1}{2}$	$\frac{9}{16}$ scant	$\frac{1}{4}$	$\frac{17}{64}$	$\frac{15}{32}$
$\frac{5}{16}$	$\frac{9}{32}$	$\frac{5}{16}$	$1\frac{3}{8}$	$1\frac{5}{16}$	$\frac{9}{32}$	$\frac{5}{16}$ scant	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{5}{16}$
$\frac{3}{8}$	$\frac{11}{32}$	$\frac{11}{32}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{11}{32}$	$\frac{11}{16}$ scant	$\frac{3}{8}$	$\frac{33}{64}$	$\frac{23}{32}$
$\frac{7}{16}$	$\frac{25}{32}$	$\frac{25}{64}$	$1\frac{5}{8}$	$1\frac{3}{8}$	$\frac{25}{32}$	$\frac{11}{32}$	$\frac{7}{16}$	$\frac{33}{64}$	$\frac{25}{32}$
$\frac{1}{2}$	$\frac{7}{8}$	$\frac{7}{16}$	$1\frac{25}{32}$	$1\frac{1}{2}$	$\frac{7}{8}$	$\frac{13}{16}$ scant	$\frac{1}{2}$	$\frac{13}{16}$	$\frac{27}{32}$
$\frac{9}{16}$	$\frac{29}{32}$	$\frac{29}{64}$	$1\frac{13}{16}$	$1\frac{5}{8}$	$\frac{29}{32}$	$\frac{29}{32}$	$\frac{9}{16}$	$\frac{29}{32}$	$\frac{29}{32}$
$\frac{5}{8}$	$1\frac{1}{16}$	$\frac{17}{32}$	2	$1\frac{13}{16}$	$1\frac{1}{16}$	$\frac{7}{8}$ full	$\frac{5}{8}$	1	$\frac{31}{32}$
$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{5}{8}$	$2\frac{3}{32}$	$1\frac{13}{16}$	$1\frac{1}{4}$	$\frac{5}{8}$ scant	$\frac{3}{4}$	$1\frac{5}{16}$	$1\frac{1}{16}$
$\frac{7}{8}$	$1\frac{7}{16}$	$\frac{23}{32}$	$2\frac{1}{2}$	$2\frac{3}{32}$	$1\frac{7}{16}$	$\frac{47}{64}$ scant	$\frac{7}{8}$	$1\frac{3}{8}$	$1\frac{5}{16}$
1	$1\frac{5}{8}$	$\frac{13}{16}$	$2\frac{3}{4}$	$2\frac{3}{8}$	$1\frac{5}{8}$	$\frac{53}{64}$ scant	1	$1\frac{7}{16}$	$1\frac{7}{16}$
$1\frac{1}{8}$	$1\frac{13}{16}$	$\frac{29}{32}$	3	$2\frac{1}{32}$	$1\frac{13}{16}$	$\frac{15}{16}$ full	$1\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{7}{16}$
$1\frac{1}{4}$	2	1	$3\frac{1}{4}$	$2\frac{7}{32}$	2	$1\frac{1}{16}$ full	$1\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{1}{8}$
$1\frac{3}{8}$	$2\frac{3}{16}$	$1\frac{3}{32}$	$3\frac{5}{16}$	3	$2\frac{3}{16}$	$1\frac{3}{16}$ full	$1\frac{3}{8}$	$2\frac{1}{16}$	$1\frac{1}{2}$
$1\frac{1}{2}$	$2\frac{3}{8}$	$1\frac{5}{16}$	$3\frac{13}{16}$	$3\frac{5}{16}$	$2\frac{3}{8}$	$1\frac{5}{16}$ full	$1\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{5}{8}$
$1\frac{5}{8}$	$2\frac{5}{16}$	$1\frac{3}{32}$	$4\frac{1}{16}$	$3\frac{1}{2}$	$2\frac{5}{16}$	$1\frac{1}{32}$ scant	$1\frac{5}{8}$	$2\frac{7}{16}$	$1\frac{3}{4}$
$1\frac{3}{4}$	$2\frac{3}{4}$	$1\frac{5}{8}$	$4\frac{3}{8}$	$3\frac{3}{4}$	$2\frac{3}{4}$	$1\frac{1}{2}$ scant	$1\frac{3}{4}$	$2\frac{5}{8}$	$1\frac{7}{8}$
$1\frac{7}{8}$	$2\frac{15}{16}$	$1\frac{13}{16}$	$4\frac{5}{8}$	4	$2\frac{15}{16}$	$1\frac{5}{8}$ scant	$1\frac{7}{8}$	$2\frac{13}{16}$	2
2	$3\frac{1}{8}$	$1\frac{5}{16}$	$4\frac{7}{8}$	$4\frac{1}{4}$	$3\frac{1}{8}$	$1\frac{23}{32}$ scant	2	3	$2\frac{1}{8}$
$2\frac{1}{4}$	$3\frac{1}{2}$	$1\frac{7}{8}$	$5\frac{7}{16}$	$4\frac{23}{32}$	$3\frac{1}{2}$	$1\frac{13}{16}$ scant	$2\frac{1}{4}$	$3\frac{3}{8}$	$2\frac{3}{8}$
$2\frac{1}{2}$	$3\frac{7}{8}$	$1\frac{15}{16}$	$5\frac{15}{16}$	$5\frac{7}{16}$	$3\frac{7}{8}$	$2\frac{7}{16}$	$2\frac{1}{2}$	$3\frac{3}{4}$	$2\frac{5}{8}$
$2\frac{3}{4}$	$4\frac{1}{4}$	$2\frac{1}{8}$	$6\frac{7}{16}$	$5\frac{1}{2}$	$4\frac{1}{4}$	$2\frac{11}{16}$	$2\frac{3}{4}$	$4\frac{1}{8}$	$2\frac{7}{8}$
3	$4\frac{5}{8}$	$2\frac{5}{16}$	7	$6\frac{7}{16}$	$4\frac{5}{8}$	$2\frac{15}{16}$	3	$4\frac{1}{2}$	$3\frac{1}{8}$

Table of Board Feet in Pieces 1 to 24 Inches Wide Up to 24 Feet Long

The table herewith shows the board feet contained in planks of a given width and length. This table is of use especially to the patternmaker but may be of value to any one having to make calculations in board measure.

Width of Board in Inches	Length of Board in Feet																	
	1′	2′	3′	4′	5′	6′	7′	8′	9′	10′	11′	12′	13′	14′	15′	16′	18′	20′	22′	24′
1″	1/12	1/6	1/4	1/3	5/12	1/2	7/12	2/3	3/4	5/6	11/12	1	1 1/12	1 1/6	1 1/4	1 1/3	1 1/2	1 2/3	1 5/6	2
2″	1/6	1/3	1/2	2/3	5/6	1	1 1/6	1 1/3	1 1/2	1 2/3	1 5/6	2	2 1/6	2 1/3	2 1/2	2 2/3	3	3 1/3	3 2/3	4
3″	1/4	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/2	5	5 1/2	6
4″	1/3	2/3	1	1 1/3	1 2/3	2	2 1/3	2 2/3	3	3 1/3	3 2/3	4	4 1/3	4 2/3	5	5 1/3	6	6 2/3	7 1/3	8
5″	5/12	5/6	1 1/4	1 2/3	2 1/12	2 1/2	2 11/12	3 1/3	3 3/4	4 1/6	4 7/12	5	5 1/12	5 5/6	6 1/4	6 2/3	7 1/2	8 1/3	9 1/6	10
6″	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6	6 1/2	7	7 1/2	8	9	10	11	12
7″	7/12	1 1/6	1 3/4	2 1/3	2 11/12	3 1/2	4 1/12	4 2/3	5 1/4	5 5/6	6 11/12	7	7 7/12	8 1/6	8 3/4	9 1/3	10 1/2	11 2/3	12 5/6	14
8″	2/3	1 1/3	2	2 2/3	3 1/3	4	4 2/3	5 1/3	6	6 2/3	7 1/3	8	8 1/3	9 1/3	10	10 2/3	12	13 1/3	14 2/3	16
9″	3/4	1 1/2	2 1/4	3	3 3/4	4 1/2	5 1/4	6	6 3/4	7 1/2	8 1/4	9	9 3/4	10 1/2	11 1/4	12	13 1/2	15	16 1/2	18
10″	5/6	1 2/3	2 1/2	3 1/3	4 1/6	5	5 5/6	6 2/3	7 1/2	8 1/3	9 1/6	10	10 5/6	11 2/3	12 1/2	13 1/3	15	16 2/3	18 1/3	20
11″	11/12	1 5/6	2 3/4	3 2/3	4 11/12	5 1/2	6 5/12	7 1/3	8 1/4	9 1/6	10 11/12	11	11 11/12	12 5/6	13 3/4	14 2/3	16 1/2	18 1/3	20 1/6	22
12″	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24
13″	1 1/12	2 1/6	3 1/4	4 1/3	5 5/12	6 1/2	7 7/12	8 2/3	9 3/4	10 5/6	11 11/12	13	14 1/12	15 1/6	16 1/4	17 1/3	19 1/2	21 2/3	23 5/6	26
14″	1 1/6	2 1/3	3 1/2	4 2/3	5 5/6	7	8 1/6	9 1/3	10 1/2	11 2/3	12 5/6	14	15 1/6	16 1/3	17 1/2	18 2/3	21	23 1/3	25 1/2	28
15″	1 1/4	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4	10	11 1/4	12 1/2	13 3/4	15	16 1/4	17 1/2	18 3/4	20	22 1/2	25	27 1/2	30
16″	1 1/3	2 2/3	4	5 1/3	6 2/3	8	9 1/3	10 2/3	12	13 1/3	14 2/3	16	17 1/3	18 2/3	20	21 1/3	24	26 2/3	29 1/3	32
17″	1 5/12	2 5/6	4 1/4	5 2/3	7 1/12	8 1/2	9 11/12	11 1/3	12 3/4	14 1/6	15 11/12	17	18 1/12	19 1/6	21 1/4	22 2/3	25 1/2	28 1/3	31 1/6	34
18″	1 1/2	3	4 1/2	6	7 1/2	9	10 1/2	12	13 1/2	15	16 1/2	18	19 1/2	21	22 1/2	24	27	30	33	36
19″	1 7/12	3 1/6	4 3/4	6 1/3	7 11/12	9 1/2	11 1/12	12 2/3	14 1/4	15 5/6	17 11/12	19	20 7/12	22 1/6	23 3/4	25 1/3	28 1/2	31 2/3	34 5/6	38
20″	1 2/3	3 1/3	5	6 2/3	8 1/3	10	11 2/3	13 1/3	15	16 2/3	18 1/3	20	21 2/3	23 1/3	25	26 2/3	30	33 1/3	36 2/3	40
21″	1 3/4	3 1/2	5 1/4	7	8 3/4	10 1/2	12 1/4	14	15 3/4	17 1/2	19 1/4	21	22 3/4	24 1/2	26 1/4	28	31 1/2	35	38 1/2	42
22″	1 5/6	3 2/3	5 1/2	7 1/3	9 1/6	11	12 5/6	14 2/3	16 1/2	18 1/3	20 1/6	22	23 5/6	25 2/3	27 1/2	29 1/3	33	36 2/3	40 1/3	44
23″	1 11/12	3 5/6	5 3/4	7 2/3	9 11/12	11 1/2	13 5/12	15 1/3	17 1/4	19 1/6	21 11/12	23	24 11/12	26 5/6	28 3/4	30 2/3	34 1/2	38 1/3	42 1/6	46
24″	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	36	40	44	48

Table gives board feet in an inch thick plank. For other thicknesses multiply by thickness in inches.

QUICK WAY OF ESTIMATING LUMBER FOR A PATTERN

MULTIPLY length, breadth, and thickness in inches together and this by 7, pointing off three places.

Board 8 inches wide, 18 inches long, 1 inch thick. $8 \times 18 \times 1 \times 7 = 1.008$ square feet. This is .008 too much, but near enough for most work. Board $1\frac{1}{2} \times 10 \times 36 = 540 \times 7 = 3.780$. The correct answer is 3.75.

TABLE GIVING PROPORTIONATE WEIGHT OF CASTINGS TO WEIGHT OF WOOD PATTERNS

A Pattern Weighing One Pound Made of (Less weight of Core Prints)	Cast Iron	Brass	Copper	Bronze	Bell Metal	Zinc
Pine or Fir	16	18.8	19.7	19.3	17	15.5
Oak	9	10.1	10.4	10.3	10.9	8.6
Beech	9.7	10.9	11.4	11.3	11.9	9.1
Linden	13.4	15.1	16.7	15.5	16.3	12.9
Pear	10.2	11.5	11.9	11.8	12.4	9.8
Birch	10.6	11.9	12.3	12.2	12.9	10.2
Alder	12.8	14.3	14.9	14.7	15.5	12.2
Mahogany	11.7	13.2	13.7	13.5	14.2	11.2
Brass	0.85	0.95	0.99	0.98	1.0	0.81

DEGREES OBTAINED BY OPENING A TWO-FOOT RULE

Degrees	Inches	Degrees	Inches	Degrees	Inches
1	.21	15	3.12	55	11.08
2	.422	20	4.17	60	12
3	.633	25	5.21	65	12.89
4	.837	30	6.21	70	13.76
5	1.04	35	7.20	75	14.61
7.5	1.57	40	8.21	80	15.43
10	2.09	45	9.20	85	16.21
14.5	3.015	50	10.12	90	16.97

Open a two-foot rule until open ends are distance apart given in table when degrees given in table can be scribed. Same results can be had with two 12-inch steel scales placed together at one end.

WEIGHT OF FILLETS

To facilitate the calculations of the weights of the different parts of a machine from the drawings, the accompanying table of areas or volumes of fillets having radii from $\frac{1}{16}$ to 3 inches can be used. It has been calculated for fillets connecting sides that are at right angles to each other.

TABLE OF AREAS OR VOLUMES OF FILLETS

Radius of Fillet in Inches	Area or Volume of Fillet in Sq. or Cubic Inches	Radius of Fillet in Inches	Area or Volume of Fillet in Sq. or Cubic Inches
$\frac{1}{16}$	.0008	$1\frac{9}{16}$	.5240
$\frac{1}{8}$	.0033	$1\frac{5}{8}$	.5667
$\frac{3}{16}$	.0075	$1\frac{11}{16}$	.6119
$\frac{1}{4}$	.0134	$1\frac{3}{4}$	.6572
$\frac{5}{16}$	.0209	$1\frac{13}{16}$	.7050
$\frac{3}{8}$	.0302	$1\frac{7}{8}$	.7543
$\frac{7}{16}$	.0410	$1\frac{15}{16}$	.8056
$\frac{1}{2}$	.0537	2	.8584
$\frac{9}{16}$	.0678	$2\frac{1}{16}$	.9129
$\frac{5}{8}$	.0838	$2\frac{1}{8}$	.9690
$\frac{11}{16}$	.1013	$2\frac{3}{16}$	1.0269
$\frac{3}{4}$	.1207	$2\frac{1}{4}$	1.0864
$\frac{13}{16}$	.1417	$2\frac{5}{16}$	1.1475
$\frac{7}{8}$	.1643	$2\frac{3}{8}$	1.2105
$\frac{15}{16}$	.1886	$2\frac{7}{16}$	1.2749
1	.2146	$2\frac{1}{2}$	1.3413
$1\frac{1}{16}$	.2423	$2\frac{9}{16}$	1.4086
$1\frac{1}{8}$	.2716	$2\frac{5}{8}$	1.4787
$1\frac{3}{16}$	.3026	$2\frac{11}{16}$	1.5500
$1\frac{1}{4}$	.3353	$2\frac{3}{4}$	1.6229
$1\frac{5}{16}$	.3697	$2\frac{13}{16}$	1.6869
$1\frac{3}{8}$	.4057	$2\frac{7}{8}$	1.7739
$1\frac{7}{16}$	.4434	$2\frac{15}{16}$	1.8518
$1\frac{1}{2}$	.4829	3	1.9314

To find the volume of a fillet by this table when the radius and length are given, multiply the value in the table opposite the given radius by the length of the fillet in inches, and this result multiplied by the weight of a cubic inch of the material will give the weight of the fillet.

LAYING OUT A SQUARE CORNER

It sometimes happens that we wish to lay out a perfectly square corner and have no square of any kind handy. Here is a way that requires nothing but a scale or rule, or even a straight stick with-

out any graduations whatever will do. Using this stick, draw a line as *A C* (Fig. 1) and at one end of this draw the line *B D* at any angle. This line must be straight, twice as long as *A C* and of equal length each side of the point *C*. Then if you join points *D A B*, you have an exact right-angle or square corner.



FIG. 1



FIG. 2

Fig. 2 is simply another example of this, in which the line *A C* has been drawn at a very different angle to show that it works in any position. Joining the ends *D A B* as before also gives an exact right angle.

ANOTHER METHOD

Another method is by what is known as the 6, 8 and 10 rule. This means that if a triangle has sides in the ratio of 6, 8 and 10, the angle is 90 degrees. Lay down a line 6 units long, either inches, feet or yards. Lay off another line 8 units long as nearly right angles as possible. Measure across the ends of the two lines and adjust until this distance is 10 units, which makes it a right angle. These distances may be 3, 4 and 5; 12, 16 and 20 or any combination in this ratio. It is largely used in laying out large corners.

TABLE SHOWING VOLUMES AND RADII OF SPHERES HAVING CAPACITIES OF $\frac{1}{4}$ PINT AND $\frac{1}{10}$ LITER AND MULTIPLES THEREOF

Pints	Volume in Cubic Inches	Radius of Sphere in Inches	Liters	Volume in Cubic Inches	Radius of Sphere in Inches
0.25	7.21875	1.1989	0.1	6.10302	1.1290
0.50	14.43750	1.5105	0.2	12.20604	1.4280
0.75	21.65625	1.7291	0.3	18.30906	1.6350
1.00	28.87500	1.9031	0.4	24.41208	1.7910
1.25	36.09375	2.0501	0.5	30.51510	1.9383
1.50	43.31250	2.1785	0.6	36.61812	2.0600
1.75	50.53125	2.2934	0.7	42.72114	2.1836
2.00	57.75000	2.3978	0.8	48.82416	2.2673
2.25	64.96875	2.4938	0.9	54.92718	2.3581
2.50	72.18750	2.5838	1.0	61.03020	2.4424
2.75	79.40625	2.6664	1.1	67.13322	2.5213
3.00	86.62500	2.7423	1.2	73.23624	2.5954
3.25	93.84375	2.8107	1.3	79.33926	2.6656
3.50	101.06250	2.8805	1.4	85.44228	2.7322
3.75	108.28125	2.9566	1.5	91.54530	2.7936
4.00	115.50000	3.0211	1.6	97.64832	2.8566
4.25	122.71875	3.0827	1.7	103.75134	2.9149
4.50	129.93750	3.1420	1.8	109.85436	2.9716
4.75	137.15625	3.1992	1.9	115.95738	3.0252
5.00	144.37500	3.2543	2.0	122.06040	3.0772
5.25	151.59375	3.3077	2.1	128.16342	3.1275
5.50	158.81250	3.3594	2.2	134.26644	3.1765
5.75	166.03125	3.4095	2.3	140.36946	3.2240
6.00	173.25000	3.4583	2.4	146.47248	3.2700
6.25	180.46875	3.5056	2.5	152.57550	3.3148
6.50	187.68750	3.5518	2.6	158.67852	3.3584
6.75	194.90625	3.5967	2.7	164.78154	3.4010
7.00	202.12500	3.6406	2.8	170.88456	3.4424
7.25	209.34375	3.6834	2.9	176.98758	3.4830
7.50	216.56250	3.7253	3.0	183.09060	3.5226
7.75	223.78125	3.7662	3.1	189.19362	3.5613
8.00	231.00000	3.8063	3.2	195.29664	3.5991
			3.3	201.39966	3.6363
			3.4	207.50268	3.6725
			3.5	213.60570	3.7082
			3.6	219.70872	3.7432
			3.7	225.81174	3.7775
			3.8	231.91476	3.8113
			3.9	238.01778	3.8445
			4.0	244.12080	3.8770

Volume of sphere $= \frac{4}{3}\pi r^3$

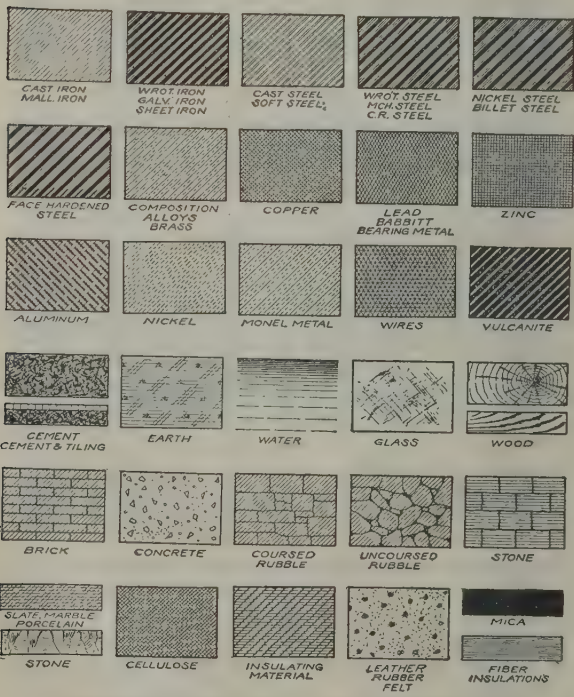
$\pi = 3.141592$

$\frac{4}{3}\pi = 4.18879$

1 liter = 0.2642 U. S. gallon or 1.0568 quarts

CROSS-SECTIONS TO DESIGNATE DIFFERENT MATERIALS

There is no universally adopted standard for designating materials on drawings, and, the subject is under consideration by the A. E. S. C., the accompanying standards are those of the General Electric Co. This gives three markings for different steels, while some use a single light and a heavy line for all steels.



Cross-section Standards Used by the General Electric Co.

WIRE GAGES AND STOCK WEIGHTS

TWIST DRILL AND STEEL WIRE GAGE SIZES

The Twist Drill and Steel Wire Gage is used for measuring the sizes of twist drills and steel drill rods. Rod sizes by this gage should not be confused with Stubs' Steel Wire Gage sizes. The difference between the sizes of corresponding numbers in the two gages ranges from about .0005 to .004 inch, the Stubs sizes being the smaller except in the cases of a few numbers where the systems coincide exactly.

Twist Drill and Steel Wire Gage Sizes

No. of Gage	Dia. in Inches	No. of Gage	Dia. in Inches	No. of Gage	Dia. in Inches	No. of Gage	Dia. in Inches
1	.2280	21	.1590	41	.0960	61	.0390
2	.2210	22	.1570	42	.0935	62	.0380
3	.2130	23	.1540	43	.0890	63	.0370
4	.2090	24	.1520	44	.0860	64	.0360
5	.2055	25	.1495	45	.0820	65	.0350
6	.2040	26	.1470	46	.0810	66	.0330
7	.2010	27	.1440	47	.0785	67	.0320
8	.1990	28	.1405	48	.0760	68	.0310
9	.1960	29	.1360	49	.0730	69	.02925
10	.1935	30	.1285	50	.0700	70	.0280
11	.1910	31	.1200	51	.0670	71	.0260
12	.1890	32	.1160	52	.0635	72	.0250
13	.1850	33	.1130	53	.0595	73	.0240
14	.1820	34	.1110	54	.0550	74	.0225
15	.1800	35	.1100	55	.0520	75	.0210
16	.1770	36	.1065	56	.0465	76	.0200
17	.1730	37	.1040	57	.0430	77	.0180
18	.1695	38	.1015	58	.0420	78	.0160
19	.1660	39	.0995	59	.0410	79	.0145
20	.1610	40	.0980	60	.0400	80	.0135

STUBS' GAGES

In using Stubs' Gages, the difference between the Stubs Iron Wire Gage and the Stubs Steel Wire Gage should be kept in mind. The Stubs Iron Wire Gage is the one commonly known as the English Standard Wire, or Birmingham Gage, and designates the Stubs soft wire sizes. The Stubs Steel Wire Gage is used in measuring drawn steel wire or drill rods of Stubs' make and is also used by many American makers of drill rods.

DIMENSIONS IN DECIMAL PARTS OF AN INCH

Number of Gage	American or Brown & Sharpe	Birmingham or Stubs' Iron Wire	Washburn & Moen Mfg. Co.	Trenton Iron Co.	Stubs' Steel Wire	Imperial Wire Gage	U. S. Standard for Plate
000000	.....	.....	.....	.....	.....	.464	.46875
00000	.....	.....	.....	.450	.....	.432	.4375
0000	.46	.454	.3938	.400	.....	.400	.40625
000	.40964	.425	.3625	.360	.....	.372	.375
00	.3648	.380	.3310	.330	.....	.348	.34375
0	.32486	.340	.3065	.305	.....	.324	.3125
1	.2893	.300	.2830	.285	.227	.300	.28125
2	.25763	.284	.2625	.265	.219	.276	.265625
3	.22942	.259	.2437	.245	.212	.252	.25
4	.20431	.238	.2253	.225	.207	.232	.234375
5	.18194	.220	.2070	.205	.204	.212	.21875
6	.16202	.203	.1920	.190	.201	.192	.203125
7	.14428	.180	.1770	.175	.199	.176	.1875
8	.12849	.165	.1620	.160	.197	.160	.171875
9	.11443	.148	.1483	.145	.194	.144	.15625
10	.10189	.134	.1350	.130	.191	.128	.140625
11	.090742	.120	.1205	.1175	.188	.116	.125
12	.080808	.109	.1055	.105	.185	.104	.109375
13	.071961	.095	.0915	.0925	.182	.092	.09375
14	.064084	.083	.0800	.080	.180	.080	.078125
15	.057068	.072	.0720	.070	.178	.072	.0703125
16	.05082	.065	.0625	.061	.175	.064	.0625
17	.045257	.058	.0540	.0525	.172	.056	.05625
18	.040303	.049	.0475	.045	.168	.048	.05
19	.03589	.042	.0410	.040	.164	.040	.04375
20	.031961	.035	.0348	.035	.161	.036	.0375
21	.028462	.032	.03175	.031	.157	.032	.034375
22	.025347	.028	.0286	.028	.155	.028	.03125
23	.022571	.025	.0258	.025	.153	.024	.028125
24	.0201	.022	.0230	.0225	.151	.022	.025
25	.0179	.020	.0204	.020	.148	.020	.021875
26	.01594	.018	.0181	.018	.146	.018	.01875
27	.014195	.016	.0173	.017	.143	.0164	.0171875
28	.012641	.014	.0162	.016	.139	.0149	.015625
29	.011257	.013	.0150	.015	.134	.0136	.0140625
30	.010025	.012	.0140	.014	.127	.0124	.0125
31	.008928	.010	.0132	.013	.120	.0116	.0109375
32	.00795	.009	.0128	.012	.115	.0108	.01015625
33	.00708	.008	.0118	.011	.112	.0100	.009375
34	.006304	.007	.0104	.010	.110	.0092	.00859375
35	.005614	.005	.0095	.0095	.108	.0084	.0078125
36	.005	.004	.0090	.009	.106	.0076	.00703125
37	.004453			.0085	.103	.0068	.006640625
38	.003965			.008	.101	.0060	.00625
39	.003531			.0075	.099	.0052	
40	.003144			.007	.097	.0048	

Wire and Drill Sizes Arranged Consecutively

Dia. of Wire	American or B. & S.	B'ham or Stubs' Wire	Stubs' Steel Wire	Twist Drill and Steel Wire	Dia. of Wire	American or B. & S.	B'ham or Stubs' Wire	Stubs' Steel Wire	Twist Drill or Steel Wire
	Gage Number					Gage Number			
.00314	40				.041			58	59
.00353	39				.042		19	57	58
.00397	38				.043				57
.004		36			.045			56	
.0045	37				.0453	17			
.005	36	35			.0465				56
.0056	35				.049		18		
.0063	34				.050			55	
.007		34			.0508	16			
.0071	33				.052				55
.008	32	33			.055			54	54
.0089	31				.0571	15			
.009		32			.058		17	53	
.010	30	31			.0595				53
.0113	29				.063			52	
.012		30			.0635				52
.0126	28				.0641	14			
.013		29	80		.065		16		
.0135				80	.066			51	
.014		28	79		.067				51
.0142	27				.069			50	
.0145				79	.070				50
.015			78		.072	13	15	49	
.0159	26				.073				49
.016		27	77	78	.075			48	
.0179	25				.076				48
.018		26	76	77	.077			47	
.020		25	75	76	.0785				47
.0201	24				.079			46	
.021				75	.0808	12			
.022		24	74		.081			45	46
.0225				74	.082				45
.0226	23				.083		14		
.023			73		.085			44	
.024			72	73	.086				44
.025		23		72	.088			43	
.0253	22				.089				43
.026			71	71	.0907	11			
.027			70		.092			42	
.028		22		70	.0935				42
.0285	21				.095		13	41	
.029			69		.096				41
.0293				69	.097			40	
.030			68		.098				40
.031			67	68	.099			39	
.032	20	21	66	67	.0995				39
.033			65	66	.101			38	
.035		20	64	65	.1015				38
.0359	19				.1019	10			
.036			63	64	.103			37	
.037			62	63	.104				37
.038			61	62	.106			36	
.039			60	61	.1065				36
.040			59	60	.108			35	
.0403	18								

Wire and Drill Sizes Arranged Consecutively

Dia. of Wire	American or B. & S.	B'ham or Stubs' Wire	Stubs' Steel Wire	Twist Drill and Steel Wire	Dia. of Wire	American or B. & S.	B'ham or Stubs' Wire	Stubs' Steel Wire	Twist Drill and Steel Wire
	Gage Number					Gage Number			
.109		12			.203		6		
.110			34	35	.204			5	6
.111				34	.2043	4			
.112			33		.2055				5
.113				33	.207			4	
.1144	9				.209				4
.115			32		.122			3	
.116				32	.213				3
.120		11	31	31	.219			2	
.127			30		.220		5		
.1285	8			30	.211				2
.134		10	29		.227			1	
.136				29	.228				1
.139			28		.2294	3			
.1405				28	.234			A	
.143			27		.238		4	B	
.144				27	.242			C	
.1443	7				.246			D	
.146			26		.250			E	
.147				26	.257			F	
.148		9	25		.2576	2			
.1495				25	.259		3		
.151			24		.261			G	
.152				24	.266			H	
.153			23		.272			I	
.154				23	.277			J	
.155			22		.281			K	
.157			21	22	.284		2		
.159				21	.2893	1			
.161			20	20	.290			L	
.162	6				.295			M	
.164			19		.300		1		
.165		8			.302			N	
.166				19	.316			O	
.168			18		.323			P	
.1695				18	.3249	0			
.172			17		.332			Q	
.173				17	.329			R	
.175			16		.340		0		
.177				16	.348			S	
.178			15		.358			T	
.180		7	14	15	.3648	00			
.1819	5				.368			U	
.182			13	14	.377			V	
.185			12	13	.380		00		
.188			11		.386			W	
.189				12	.397			X	
.191			10	11	.404			Y	
.1935				10	.4096	000			
.194			9		.413			Z	
.196				9	.425		000		
.197			8		.454		0000		
.199			7	8	.460	0000			
.201			6	7					

STUBS' STEEL WIRE SIZES AND WEIGHTS

As stated in the explanatory note regarding Stubs' Gages at the bottom of page 635 the Stubs steel wire gage is used for measuring drawn steel wire and drill rods of Stubs' make and is also used by various drill rod makers in America.

STUBS' STEEL WIRE SIZES, AND WEIGHT IN POUNDS PER LINEAR FOOT

Letter and No. of Gage	Dia. in Inches	Weight per Foot	No. of Wire Gage	Dia. in Inches	Weight per Foot	No. of Wire Gage	Dia. in Inches	Weight per Foot
Z	.413	.456	10	.191	.098	46	.079	.017
Y	.404	.437	11	.188	.095	47	.077	.016
X	.397	.422	12	.185	.092	48	.075	.015
W	.386	.399	13	.182	.089	49	.072	.014
V	.377	.380	14	.180	.087	50	.069	.013
U	.368	.362	15	.178	.085	51	.066	.012
T	.358	.335	16	.175	.082	52	.063	.011
S	.348	.324	17	.172	.079	53	.058	.009
R	.339	.307	18	.168	.075	54	.055	.008
Q	.332	.295	19	.164	.072	55	.050	.007
P	.323	.280	20	.161	.069	56	.045	.006
O	.316	.267	21	.157	.066	57	.042	.0047
N	.302	.244	22	.155	.064	58	.041	.0045
M	.295	233	23	.153	.063	59	.040	.0042
L	.290	.225	24	.151	.061	60	.039	.0040
K	.281	.211	25	.148	.059	61	.038	.0039
J	.277	.205	26	.146	.057	62	.037	.0037
I	.272	.192	27	.143	.055	63	.036	.0035
H	.266	.189	28	.139	.052	64	.035	.0033
G	.261	.182	29	.134	.048	65	.033	.0029
F	.257	.177	30	.127	.043	66	.032	.0027
E	.250	.167	31	.120	.039	67	.031	.0026
D	.246	.162	32	.115	.035	68	.030	.0024
C	.242	.159	33	.112	.034	69	.029	.0022
B	.238	.152	34	.110	.032	70	.027	.0020
A	.234	.146	35	.108	.031	71	.026	.0018
1	.227	.138	36	.106	.030	72	.024	.0015
2	.219	.128	37	.103	.028	73	.023	.0014
3	.212	.120	38	.101	.027	74	.022	.0013
4	.207	.115	39	.099	.026	75	.020	.0011
5	.204	.111	40	.097	.025	76	.018	.0009
6	.201	.108	41	.095	.024	77	.016	.0007
7	.199	.106	42	.092	.023	78	.015	.0006
8	.197	.104	43	.088	.020	79	.014	.0005
9	.194	.101	44	.085	.019	80	.013	.0004
			45	.081	.018			

MUSIC WIRE SIZES

No. of Gage	Washburn & Moen	Webster & Horsefall	No. of Gage	Washburn & Moen	Webster & Horsefall	No. of Gage	Washburn & Moen	Webster & Horsefall
8–0	.0083		6	.0215	.016	19	.0414	.043
7–0	.0087		7	.023	.018	20	.0434	.045
6–0	.0095		8	.0243	.020	21	.046	.047
5–0	.010		9	.0256	.022	22	.0483	.052
4–0	.011	.006	10	.027	.024	23	.051	.055
3–0	.012	.007	11	.0284	.026	24	.055	.059
2–0	.0133	.008	12	.0296	.029	25	.0586	.061
1–0	.0144	.009	13	.0314	.031	26	.0626	.065
1	.0156	.010	14	.0326	.033	27	.0658	.070
2	.0166	.011	15	.0345	.035	28	.072	.072
3	.0178	.012	16	.036	.037	29	.076	.077
4	.0188	.013	17	.0377	.039	30	.080	.083
5	.0202	.014	18	.0395	.041			

WEIGHT AND APPROXIMATE THICKNESS OF SHEET STEEL

U. S. Standard Gage

The U. S. gage is a weight and not a thickness gage, being based on wrought iron at 0.2778 pounds per cubic inch or 480 pounds per cubic foot. The numbers, or gage thicknesses, were to give definite weight per square foot, No. 0000000 being 0.5 inch and wrought iron of this gage weighing 20 pounds per square foot.

Because steel has almost entirely superseded wrought iron for sheet use since the U. S. gage was established, the density of rolled steel, 0.2833 pound per cubic inch, or 489.6 pounds per cubic foot has been adopted by the Association of American Steel Manufacturers, the A. S. T. M., and approved by the Bureau of Standards. Thicknesses in the following table are of steel equivalent to the unit weights of the U. S. Standard gage. Steel is, however, rolled to any decimal thickness to meet requirements.

Sheets up to and including No. 5, or 0.2145 in. are called "sheets"—above this they are called "plates."

Number of U. S. Gage	Approximate Thickness in Decimal Parts of an Inch	Weight per Square Foot in Pounds Black	Weight per Square Foot in Pounds Galvanized
0000000	0.490	20 00	
000000	0.460	18.75	
00000	0.429	17.50	
0000	0.398	16.25	
000	0.368	15	
00	0.337	13.75	
0	0.306	12.50	
1	0.2758	11.25	
2	0.2604	10.625	
3	0.2451	10	
4	0.2298	9.375	
5	0.2145	8.75	
6	0.1992	8.125	
7	0.1838	7.5	
8	0.1685	6.875	7.031
9	0.1532	6.25	6.406
10	0.1379	5.625	5.781
11	0.1226	5	5.156
12	0.1072	4.375	4.531
13	0.0919	3.75	3.906
14	0.0766	3.125	3.281
15	0.0689	2.8125	2.969
16	0.0613	2.5	2.656
17	0.0552	2.25	2.406
18	0.0490	2	2.156
19	0.0429	1.75	1.906
20	0.0368	1.50	1.656
21	0.0337	1.375	1.531
22	0.0306	1.25	1.406
23	0.0276	1.125	1.281
24	0.0245	1	1.156
25	0.0214	0.875	1.031
26	0.0184	0.75	0.906
27	0.0169	0.6875	0.844
28	0.0153	0.625	0.781

Weights of Steel, Wrought Iron, Brass and Copper Plates
American or Brown & Sharpe Gage

No. of Gage	Thickness in Inches	Weight in Lbs. per Square Foot		
		Aluminum	Brass	Copper
0000	.46	6.48	19.688	20.838
000	.4096	5.77	17.533	18.557
00	.3648	5.14	15.613	16.525
0	.3249	4.58	13.904	14.716
1	.2893	4.08	12.382	13.105
2	.2576	3.63	11.027	11.670
3	.2294	3.23	9.819	10.392
4	.2043	2.88	8.745	9.255
5	.1819	2.56	7.788	8.242
6	.1620	2.28	6.935	7.340
7	.1443	2.03	6.175	6.536
8	.1285	1.81	5.499	5.821
9	.1144	1.61	4.898	5.183
10	.1019	1.44	4.631	4.616
11	.0908	1.28	3.884	4.110
12	.0808	1.14	3.458	3.660
13	.0720	1.01	3.080	3.260
14	.0641	.903	2.743	2.903
15	.0571	.804	2.442	2.585
16	.0508	.716	2.175	2.302
17	.0453	.638	1.937	2.050
18	.0403	.568	1.725	1.825
19	.0359	.506	1.536	1.626
20	.0320	.450	1.367	1.448
21	.0285	.401	1.218	1.289
22	.0253	.357	1.085	1.148
23	.0226	.318	.966	1.023
24	.0201	.283	.860	.910
25	.0179	.252	.766	.811
26	.0159	.225	.682	.722
27	.0142	.200	.608	.643
28	.0126	.178	.541	.573
29	.0113	.159	.482	.510
30	.0100	.141	.429	.454
31	.0089	.126	.382	.404
32	.0080	.113	.340	.360
33	.0071	.100	.303	.321
34	.0063	.0888	.269	.286
35	.0056	.0790	.240	.254
36	.0050	.0704	.214	.226
37	.0045	.0627	.191	.202
38	.0040	.0558	.170	.180
39	.0035	.0497	.151	.160
40	.0031	.0442	.135	.142

Weights of Steel, Wrought Iron, Brass and Copper Plates
Birmingham or Stubs' Gage

No. of Gage	Thickness in Inches	Weight in Lbs. per Square Foot			
		Steel	Iron	Brass	Copper
0000	.454	18.52	18.16	19.431	20.556
000	.425	17.34	17.00	18.190	19.253
00	.380	15.30	15.20	16.264	17.214
0	.340	13.87	13.60	14.552	15.402
1	.300	12.24	12.00	12.840	13.590
2	.284	11.59	11.36	12.155	12.865
3	.259	10.57	10.36	11.085	11.733
4	.238	9.71	9.52	10.186	10.781
5	.220	8.98	8.80	9.416	9.966
6	.203	8.28	8.12	8.689	9.196
7	.180	7.34	7.20	7.704	8.154
8	.165	6.73	6.60	7.062	7.475
9	.148	6.04	5.92	6.334	6.704
10	.134	5.47	5.36	5.735	6.070
11	.120	4.90	4.80	5.137	5.436
12	.109	4.45	4.36	4.667	4.938
13	.095	3.88	3.80	4.066	4.303
14	.083	3.39	3.32	3.552	3.769
15	.072	2.94	2.88	3.081	3.262
16	.065	2.65	2.60	2.782	2.945
17	.058	2.37	2.32	2.482	2.627
18	.049	2.00	1.96	2.097	2.220
19	.042	1.71	1.68	1.797	1.902
20	.035	1.43	1.40	1.498	1.585
21	.032	1.31	1.28	1.369	1.450
22	.028	1.14	1.12	1.198	1.270
23	.025	1.02	1.00	1.070	1.132
24	.022	.898	.88	.941	.997
25	.020	.816	.80	.856	.906
26	.018	.734	.72	.770	.815
27	.016	.653	.64	.685	.725
28	.014	.571	.56	.599	.634
29	.013	.530	.52	.556	.589
30	.012	.490	.48	.514	.544
31	.010	.408	.40	.428	.453
32	.009	.367	.36	.385	.408
33	.008	.326	.32	.342	.362
34	.007	.286	.28	.2996	.317
35	.005	.204	.20	.214	.227
36	.004	.163	.16	.171	.181

Weights of Steel, Iron, Brass and Copper Wire
American or Brown & Sharpe Gage

No. of Gage	Dia. in Inches	Weight in Lbs. per 1000 Linear Feet			
		Steel	Iron	Brass	Copper
0000	.4600	566.03	560.74	605.18	640.51
000	.4096	448.88	444.68	479.91	507.95
00	.3648	355.99	352.66	380.67	402.83
0	.3247	282.30	279.67	301.82	319.45
1	.2893	223.89	221.79	239.35	253.34
2	.2576	177.55	175.89	189.82	200.91
3	.2294	140.80	139.48	150.52	159.32
4	.2043	111.66	110.62	119.38	126.35
5	.1819	88.548	87.720	94.666	100.20
6	.1620	70.221	69.565	75.075	79.462
7	.1443	55.685	55.165	59.545	63.013
8	.1285	44.164	43.751	47.219	49.976
9	.1144	35.026	34.699	37.437	39.636
10	.1019	27.772	27.512	29.687	31.426
11	.0907	22.026	21.820	23.549	24.924
12	.0808	17.468	17.304	18.676	19.766
13	.0720	13.851	13.722	14.809	15.674
14	.0641	10.989	10.886	11.746	12.435
15	.0571	8.712	8.631	9.315	9.859
16	.0508	6.909	6.845	7.587	7.819
17	.0453	5.478	5.427	5.857	6.199
18	.0403	4.344	4.304	4.645	4.916
19	.0359	3.445	3.413	3.684	3.899
20	.0320	2.734	2.708	2.920	3.094
21	.0285	2.167	2.147	2.317	2.452
22	.0253	1.719	1.703	1.838	1.945
23	.0226	1.363	1.350	1.457	1.542
24	.0201	1.081	1.071	1.155	1.223
25	.0179	.8571	.8491	.9163	.9699
26	.0159	.6797	.6734	.7267	.7692
27	.0142	.5391	.5340	.5763	.6099
28	.0126	.4275	.4235	.4570	.4837
29	.0113	.3389	.3358	.3624	.3835
30	.0100	.2688	.2663	.2874	.3042
31	.0089	.2132	.2113	.2280	.2413
32	.0080	.1691	.1675	.1808	.1913
33	.0071	.1341	.1328	.1434	.1517
34	.0063	.1063	.1053	.1137	.1204
35	.0056	.0844	.0836	.0901	.0956
36	.0050	.0668	.0662	.0715	.0757
37	.0045	.0530	.0525	.0567	.0600
38	.0040	.0420	.0416	.0449	.0475
39	.0035	.0333	.0330	.0356	.0375
40	.0031	.0264	.0262	.0282	.0299

Weights of Iron, Brass, and Copper Wire
Birmingham or Stubs' Gage

No. of Gage	Dia. in Inches	Weight in Lbs. per 1000 Linear Feet		
		Iron	Brass	Copper
0000	.454	546.21	589.29	623.2
000	.425	478.65	516.41	546.1
00	.380	382.66	412.84	436.6
0	.340	306.34	330.50	349.5
1	.300	238.50	257.31	272.1
2	.284	213.74	230.60	243.9
3	.259	177.77	191.79	202.8
4	.238	150.11	161.95	171.3
5	.220	128.26	138.37	146.3
6	.203	109.20	117.82	124.6
7	.180	85.86	92.63	97.96
8	.165	72.14	77.83	82.31
9	.148	58.05	62.62	66.23
10	.134	47.58	51.34	54.29
11	.120	38.16	41.17	43.54
12	.109	31.49	33.97	35.92
13	.095	23.92	25.80	27.29
14	.083	18.26	19.70	20.83
15	.072	13.73	14.82	15.67
16	.065	11.19	12.08	12.77
17	.058	8.92	9.62	10.17
18	.049	6.36	6.86	7.259
19	.042	4.67	5.04	5.333
20	.035	3.25	3.52	3.704
21	.032	2.71	2.93	3.096
22	.028	2.08	2.24	2.370
23	.025	1.66	1.79	1.890
24	.022	1.28	1.39	1.463
25	.020	1.06	1.14	1.209
26	.018	.863	.926	.979
27	.016	.680	.732	.774
28	.014	.529	.560	.592
29	.013	.438	.483	.511
30	.012	.382	.412	.435
31	.010	.266	.286	.302
32	.009	.212	.232	.244
33	.008	.167	.183	.193
34	.007	.133	.140	.148
35	.005	.066	.071	.075
36	.004	.046	.048	.052

Weights of Steel and Iron Bars per Linear Foot

Dia. or Distance Across Flats	Steel				Iron	
	Weight per Foot				Weight per Foot	
	Round	Square	Hexagon	Octagon	Round	Square
1/16	.010	.013	.012	.011	.010	.013
1/8	.042	.053	.046	.044	.041	.052
3/16	.094	.119	.103	.099	.092	.117
1/4	.167	.212	.185	.177	.164	.208
5/16	.261	.333	.288	.277	.256	.326
3/8	.375	.478	.414	.398	.368	.469
7/16	.511	.651	.564	.542	.501	.638
1/2	.667	.850	.737	.708	.654	.833
9/16	.845	1.076	.932	.896	.828	1.055
5/8	1.043	1.328	1.151	1.107	1.023	1.302
11/16	1.262	1.608	1.393	1.331	1.237	1.576
3/4	1.502	1.913	1.658	1.584	1.473	1.875
13/16	1.763	2.245	1.944	1.860	1.728	2.201
7/8	2.044	2.603	2.256	2.156	2.004	2.552
15/16	2.347	2.989	2.591	2.482	2.301	2.930
1	2.670	3.400	2.947	2.817	2.618	3.333
1 1/16	3.014	3.838	3.327	3.182	2.955	3.763
1 1/8	3.379	4.303	3.730	3.568	3.313	4.219
1 3/16	3.766	4.795	4.156	3.977	3.692	4.701
1 1/4	4.173	5.312	4.605	4.407	4.091	5.208
1 5/16	4.600	5.857	5.077	4.858	4.510	5.742
1 3/8	5.049	6.428	5.571	5.331	4.950	6.302
1 7/16	5.518	7.026	6.091	5.827	5.410	6.888
1 1/2	6.008	7.650	6.631	6.344	5.890	7.500
1 9/16	6.520	8.301	7.195	6.905	6.392	8.138
1 5/8	7.051	8.978	7.776	7.446	6.913	8.802
1 11/16	7.604	9.682	8.392	8.027	7.455	9.492
1 3/4	8.178	10.41	9.025	8.635	8.018	10.21
1 13/16	8.773	11.17	9.682	9.264	8.601	10.95
1 7/8	9.388	11.95	10.36	9.918	9.204	11.72
1 15/16	10.02	12.76	11.06	10.58	9.828	12.51
2	10.68	13.60	11.79	11.28	10.47	13.33
2 1/8	12.06	15.35	13.31	12.71	11.82	15.05
2 1/4	13.52	17.22	14.92	14.24	13.25	16.88
2 3/8	15.07	19.18	16.62	15.88	14.77	18.80
2 1/2	16.69	21.25	18.42	17.65	16.36	20.83
2 5/8	18.40	23.43	20.31	19.45	18.04	22.97
2 3/4	20.20	25.71	22.29	21.28	19.80	25.21
2 7/8	22.07	28.10	24.36	23.28	21.64	27.55
3	24.03	30.60	26.53	25.36	23.56	30.00
3 1/8	26.08	33.20	28.78	27.50	25.57	32.55
3 1/4	28.20	35.92	31.10	29.28	27.65	35.21
3 3/8	30.42	38.78	33.57	32.10	29.82	37.97
3 1/2	32.71	41.65	36.10	34.56	32.07	40.83
3 5/8	35.09	44.68	38.73	37.05	34.40	43.80
3 3/4	37.56	47.82	41.45	39.68	36.82	46.88
3 7/8	40.10	51.05	44.26	42.35	39.31	50.05
4	42.73	54.40	47.16	45.12	41.89	53.33

Weights of Brass, Copper and Aluminum Bars per Linear Foot

Dia. or Distance Across Flats	Brass			Copper		Aluminum	
	Weight per Foot			Weight per Foot		Weight per Foot	
	Round	Square	Hexagon	Round	Square	Round	Square
1/16	.011	.014	.013	.012	.015	.003	.004
1/8	.045	.055	.048	.047	.060	.014	.018
3/16	.100	.125	.108	.106	.135	.032	.041
1/4	.175	.225	.194	.189	.241	.057	.072
5/16	.275	.350	.301	.296	.377	.089	.114
3/8	.395	.510	.436	.426	.542	.128	.163
7/16	.540	.690	.592	.579	.737	.174	.222
1/2	.710	.905	.773	.757	.964	.227	.290
9/16	.900	1.15	.978	.958	1.22	.288	.367
5/8	1.10	1.40	1.24	1.18	1.51	.356	.453
11/16	1.35	1.72	1.45	1.43	1.82	.430	.548
3/4	1.66	2.05	1.73	1.70	2.17	.516	.652
13/16	1.85	2.40	2.03	2.00	2.54	.601	.766
7/8	2.15	2.75	2.36	2.32	2.95	.697	.888
15/16	2.48	3.15	2.71	2.66	3.39	.800	1.02
1	2.85	3.65	3.10	3.03	3.86	.911	1.16
1 1/16	3.20	4.08	3.49	3.42	4.35	1.03	1.31
1 1/8	3.57	4.55	3.91	3.81	4.88	1.15	1.47
1 3/16	3.97	5.08	4.38	4.27	5.44	1.28	1.64
1 1/4	4.41	5.65	4.82	4.72	6.01	1.42	1.81
1 5/16	4.86	6.22	5.33	5.21	6.63	1.57	2.00
1 3/8	5.35	6.81	5.76	5.72	7.24	1.72	2.19
1 7/16	5.86	7.45	6.38	6.26	7.97	1.88	2.40
1 1/2	6.37	8.13	6.92	6.81	8.67	2.05	2.61
1 9/16	6.92	8.83	7.54	7.39	9.41	2.22	2.83
1 5/8	7.48	9.55	8.15	7.99	10.18	2.41	3.06
1 11/16	8.05	10.27	8.80	8.45	10.73	2.59	3.30
1 3/4	8.65	11.00	9.47	9.27	11.80	2.79	3.55
1 13/16	9.29	11.82	10.15	9.76	12.43	2.99	3.81
1 7/8	9.95	12.68	10.86	10.64	13.55	3.20	4.08
1 15/16	10.58	13.50	11.68	11.11	14.15	3.41	4.35
2	11.25	14.35	12.36	12.11	15.42	3.64	4.64
2 1/8	12.78	16.27	13.92	13.67	17.42	4.11	5.24
2 1/4	14.32	18.24	15.72	15.33	19.51	4.61	5.87
2 3/8	15.96	20.32	17.52	17.08	21.74	5.14	6.54
2 1/2	17.68	22.53	19.44	18.92	24.09	5.69	7.25
2 5/8	19.50	24.83	21.24	20.86	26.56	6.27	7.99
2 3/4	21.40	27.25	23.40	22.89	29.05	6.89	8.53
2 7/8	23.39	29.78	25.82	25.02	31.86	7.52	9.58
3	25.47	32.43	27.84	27.24	34.69	8.20	10.44
3 1/4	30.45	38.77	32.76	31.97	40.71	9.62	12.25
3 1/2	35.31	44.96	37.80	37.08	47.22	11.16	14.21
3 3/4	40.07	51.01	43.56	42.11	53.61	12.81	16.31
4	46.12	58.73	49.44	48.43	61.67	14.56	18.56

Weights of Flat Sizes of Steel in Pounds per Linear Foot

	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1¾	2	2¼	2½	2¾	3	3½	4	5	6
1/8	.213	.266	.320	.372	.426	.479	.530	.585	.640	.745	.850	.955	1.07	1.18	1.28	1.49	1.70	2.13	2.56
3/16	.319	.399	.480	.558	.639	.718	.790	.878	.960	1.12	1.28	1.43	1.60	1.76	1.92	2.24	2.55	3.20	3.83
¼	.425	.533	.640	.743	.852	.958	1.06	1.17	1.28	1.49	1.70	1.91	2.13	2.34	2.56	2.98	3.40	4.26	5.11
5/16	.531	.665	.800	.929	1.06	1.20	1.33	1.46	1.60	1.86	2.13	2.39	2.66	2.92	3.19	3.72	4.25	5.32	6.38
⅜	.638	.798	.960	1.12	1.28	1.43	1.59	1.75	1.91	2.23	2.55	2.87	3.20	3.51	3.83	4.46	5.10	6.40	7.66
7/16	.744	.931	1.12	1.30	1.49	1.67	1.86	2.05	2.23	2.60	2.98	3.35	3.72	4.09	4.46	5.21	5.95	7.44	8.92
½	..	1.07	1.28	1.49	1.70	1.91	2.13	2.34	2.55	2.98	3.40	3.83	4.26	4.68	5.10	5.96	6.80	8.52	10.20
9/16	..	1.20	1.44	1.67	1.91	2.15	2.39	2.63	2.87	3.35	3.83	4.30	4.78	5.26	5.74	6.69	7.65	9.56	11.50
⅝	..	..	1.60	1.86	2.12	2.39	2.66	2.92	3.19	3.72	4.26	4.79	5.32	5.86	6.39	7.44	8.52	10.64	12.78
11/16	..	..	1.76	2.04	2.34	2.63	2.92	3.22	3.51	4.09	4.68	5.26	5.84	6.43	7.01	8.18	9.35	11.70	14.00
¾	..	..	..	2.23	2.55	2.86	3.19	3.50	3.83	4.46	5.10	5.74	6.40	7.02	7.65	8.92	10.20	12.80	15.30
13/16	..	..	..	2.41	2.76	3.11	3.45	3.80	4.14	4.83	5.53	6.22	6.91	7.60	8.29	9.67	11.10	13.80	16.60
⅞	..	..	..	..	2.98	3.34	3.72	4.09	4.46	5.21	5.96	6.70	7.46	8.19	8.94	10.42	11.92	14.92	17.88
15/16	..	..	..	..	..	3.19	3.59	3.98	4.38	4.78	5.58	6.38	7.17	7.97	8.77	9.56	11.20	12.80	15.90	19.10
1	..	..	..	..	..	..	3.82	4.25	4.68	5.10	5.96	6.80	7.66	8.52	9.36	10.20	11.92	13.60	17.04	20.40
1⅛	..	..	..	..	..	..	..	4.78	5.27	5.74	6.71	7.65	8.61	9.59	10.54	11.48	13.41	15.30	19.17	22.95
1¼	..	..	..	..	..	..	..	..	5.85	6.38	7.45	8.50	9.57	10.65	11.71	12.76	14.90	17.00	21.30	25.61
1½	..	..	.	..	..	..	..	..	7.02	7.67	8.94	10.20	11.49	12.78	14.04	15.30	17.88	20.40	25.56	30.

Weights of Seamless Brass Tubing per Linear Foot. ($\frac{1}{8}$ to $2\frac{1}{2}$ outside diameter. Nos. 1 to 25 stubs gage)

No. of Gage	Thickness in Inches	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$
1	.300	..	..	..	..	..	.	..	..	..	..	..	2.42	3.28	4.10	5.03	5.88	6.75	7.62
2	.284	..	..	.	..	..	.	..	.	..	..	..	2.35	3.16	4.03	4.80	5.57	6.45	7.26
3	259	..	..	..	..	.	.	..	.	..	..	1.85	2.22	2.98	3.72	4.48	5.23	5.96	6.72
4	.238	..	..	..	..	.	.	..	.	..	..	1.76	2.10	2.79	3.49	4.18	4.82	5.51	6.25
5	.220	..	..	..	.	.	.	..	.	..	..	1.68	1.99	2.60	3.26	3.89	4.53	5.14	5.80
6	.203	..	..	..	..	.	.	.	1.00	1.29	1.58	1.88	2.46	3.04	3.60	4.20	4.80	5.39	
7	.180	..	.	..	.	.	.	..	.	.90	1.19	1.44	1.71	2.23	2.77	3.28	3.78	4.33	4.83
8	.165	.	..	..	..	.40	.52	.64	.77	.87	1.11	1.35	1.59	2.07	2.54	3.02	3.50	3.98	4.46
9	.148	.	.	.	..	.39	.49	.61	.71	.82	1.04	1.25	1.46	1.89	2.32	2.75	3.17	3.60	4.03
10	.134	..	..	..	..	.38	.46	.58	.65	.77	.96	1.16	1.35	1.74	2.12	2.51	2.90	3.28	3.67
11	.120	..	..	.18	.26	.36	.43	.53	.61	.70	.87	1.05	1.22	1.57	1.91	2.27	2.16	2.96	3.31
12	.109	.	..	.177	.256	.334	.413	.491	.570	.650	.808	.965	1.12	1.43	1.76	2.07	2.39	2.70	3.01
13	.095	..	..	.170	.237	.306	.377	.445	.514	.580	.717	.855	1.00	1.27	1.55	1.82	2.09	2.37	2.65
14	.083	..	..	.160	.220	.280	.340	.400	.460	.520	.640	.760	.88	1.12	1.36	1.61	1.84	2.08	2.32
15	.072	..	.096	.144	.201	.251	.303	.355	.409	.461	.564	.667	.77	.99	1.19	1.40	1.61	1.81	2.02
16	.065	..	.092	.138	.186	.232	.279	.326	.372	.420	.515	.609	.70	.89	1.07	1.26	1.45	1.64	1.82
17	.058	.044	.087	.128	.169	.212	.255	.295	.338	.380	.463	.548	.64	.80	.97	1.14	1.30	1.48	1.64
18	.049	.043	.078	.113	.150	.183	.220	.255	.291	.325	.397	.467	.54	.67	.82	.96	1.10	1.24	1.39
19	.042	.040	.070	.101	.130	.161	.193	.221	.252	.282	.343	.404	.46	.58	.71	.83	.95	1.07	1.19
20	.035	.036	.062	.086	.113	.136	.163	.188	.214	.238	.289	.339	.39	.49	.59	.69	.80	.893	1.00
21	.032	.034	.057	.081	.104	.128	.151	.173	.196	.219	.266	.312	.357	.450	.542	.635	.727	.820	.913
22	.028	.031	.051	.072	.093	.112	.133	.152	.174	.192	.233	.275	.315	.396	.477	.556	.638	.718	.799
23	.025	.029	.047	.066	.082	.102	.119	.136	.155	.173	.209	.245	.281	.354	.426	.497	.571	.641	.714
24	.022	.026	.042	.058	.074	.090	.107	.121	.137	.154	.186	.218	.249	.312	.376	.438	.502	.566	.629
25	.020	.024	.039	.052	.068	.081	.096	.110	.126	.140	.169	.197	.226	.285	.342	.399	.457	.516	.573

For Weights of Seamless Copper Tubing, add 5 per cent. to the weights above.

"Shelby" Cold-Drawn Seamless Steel Tubing—Round
(Weight in Pounds per Foot)

Thickness B.W.G. & Fractions	Equivalent in Decimal of Inch	Outside Diameter in Inches																		
		½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜	2½	2⅝	2¾
20	0.035	0.17	0.22	0.27	0.31	0.36	0.41	0.45												
18	0.049	0.24	0.30	0.37	0.43	0.50	0.56	0.63	0.69	0.76	0.82									
16	0.065	0.30	0.39	0.47	0.56	0.65	0.74	0.82	0.91	1.00	1.08	1.17	1.26	1.34	1.43	1.52	1.60	1.69		
14	0.083	0.37	0.48	0.59	0.70	0.81	0.92	1.03	1.14	1.25	1.37	1.48	1.59	1.70	1.81	1.92	2.03	2.14	2.25	2.36
13	0.090	0.41	0.54	0.66	0.79	0.92	1.04	1.17	1.30	1.42	1.55	1.68	1.80	1.93	2.06	2.19	2.31	2.44	2.56	2.69
12	0.109	0.45	0.60	0.75	0.89	1.04	1.18	1.33	1.47	1.62	1.76	1.91	2.06	2.20	2.35	2.49	2.63	2.78	2.93	3.07
11	0.120	0.49	0.65	0.81	0.97	1.13	1.29	1.45	1.61	1.77	1.93	2.09	2.25	2.41	2.57	2.73	2.89	3.05	3.21	3.37
10	0.134	0.52	0.70	0.88	1.06	1.24	1.42	1.60	1.77	1.95	2.13	2.31	2.49	2.67	2.85	3.03	3.21	3.39	3.56	3.74
9/32	0.156			0.99	1.20	1.41	1.61	1.82	2.03	2.24	2.45	2.66	2.87	3.07	3.28	3.49	3.70	3.91	4.12	4.32
3/16	0.188			1.13	1.38	1.63	1.88	2.13	2.38	2.63	2.88	3.13	3.38	3.63	3.88	4.13	4.38	4.63	4.88	5.13
7/32	0.219				1.53	1.82	2.12	2.41	2.70	2.99	3.28	3.57	3.87	4.16	4.48	4.74	5.03	5.32	5.62	5.91
¼	0.250					2.00	2.33	2.67	3.00	3.33	3.67	4.00	4.33	4.67	5.00	5.33	5.67	6.00	6.33	6.67
9/32	0.281							2.91	3.28	3.66	4.03	4.41	4.78	5.16	5.53	5.91	6.28	6.66	7.03	7.41
5/16	0.313							3.13	3.54	3.96	4.38	4.79	5.21	5.63	6.04	6.46	6.88	7.29	7.71	8.13
3/8	0.375							3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.50	7.00	8.00	8.50	9.00	9.51
7/16	0.438								4.38	4.96	5.54	6.13	6.71	7.29	7.88	8.46	9.04	9.63	10.21	10.79
½	0.500									5.33	6.00	6.67	7.33	8.00	8.67	9.34	10.00	10.67	11.34	12.00
9/16	0.562											7.13	7.88	8.63	9.38	10.13	10.88	11.63	12.38	13.13
⅝	0.625													9.17	10.00	10.84	11.67	12.50	13.34	14.17
¾	0.750																	14.00	15.00	16.00
7/8	0.875																			
1"	1.000																			

Hot rolled from 2-inch diameter No. 11 gage to 9 inches and 1 inch thick. Same weights as above.

DECIMAL THICKNESS TABLE FOR SHEET COPPER

Sheet copper is frequently designated by the weight in ounces of a square foot instead of by its thickness. This table prevents the necessity of weighing and measuring.

THICKNESS OF COPPER FROM 3 TO 253 OUNCES PER SQUARE FOOT

Ounces per Square Foot	Decimal Thickness, Inches	Ounces per Square Foot	Decimal Thickness, Inches
3	0.004	64	0.083
4	0.005	70	0.095
6	0.008	81	0.109
8	0.010	89	0.120
10	0.013	100	0.134
12	0.016	110	0.148
14	0.018	123	0.165
16	0.022	134	0.180
18	0.025	151	0.203
20	0.028	164	0.220
24	0.032	177	0.238
32	0.042	193	0.259
40	0.049	211	0.284
48	0.065	223	0.300
56	0.072	253	0.340

Buffalo, N. Y. H. B. KELLAM

GAGES USED IN U. S. FOR DIFFERENT MATERIAL

Name of Gage	Used for Gaging
American Wire or Brown & Sharpe	Brass, bronze, copper and other non-ferrous wires and sheets
Birmingham, or Stub's iron wire	Telegraph and telephone wire. Also to some extent for non-ferrous sheets and the wall thickness of tubing.
Music wire	Piano and other music wire
Sheet zinc	Zinc sheets
Steel wire, or Washburn Moen	Steel wire except music wire and drill rod
Twist drill and steel wire	Twist drills and drill rods
U. S. Standard for sheets and plates	Sheet and plate iron and steel—really more of a gage of weight per square foot than of thickness

GAGE AND WEIGHT OF ZINC SHEET

Sheet zinc rolled in the U. S. is measured by the American Standard zinc gage. The table is supplied by the Illinois Zinc Company. The numbers run opposite to most metal gages, the smaller numbers being the thinnest metal.

Illinois Zinc Company's Zinc Gage

No.	Lbs. per Square Foot	Thickness in Inches	No.	Lbs. per Square Foot	Thickness in Inches
3	0.22	0.006	16	1.68	0.045
4	0.30	0.008	17	1.87	0.050
5	0.37	0.010$\frac{1}{10}$	18	2.06	0.055
6	0.45	0.012	19	2.25	0.060$\frac{1}{17}$
7	0.52	0.014	20	2.62	0.070
8	0.60	0.016	21	3.00	0.080
9	0.67	0.018	22	3.37	0.090
10	0.75	0.020$\frac{1}{10}$	23	3.75	0.100$\frac{1}{10}$
11	0.90	0.024	24	4.70	0.125$\frac{1}{8}$
12	1.05	0.028	25	9.40	0.250$\frac{1}{4}$
13	1.20	0.032	26	14.00	0.375$\frac{3}{8}$
14	1.35	0.036	27	18.75	0.500
15	1.50	0.040$\frac{1}{25}$	28	37.50	1.000

HORSE-POWER, BELTS AND SHAFTING

Horse-Power

HORSE-POWER is an arbitrary unit of measurement which has been adopted for measuring the work of engines or machines. It is given as 33,000 foot pounds per minute which means 1 pound lifted 33,000 feet per minute or 33,000 pounds lifted 1 foot per minute or 330 pounds lifted 100 feet per minute, or any combination which gives 33,000 foot pounds per minute.

Steam Engine Horse-Power

In a steam engine it means the effective steam pressure per square inch, times the length of piston movement per revolution in feet, times the piston area in square inches, times the number of revolutions per minute, and all divided by 33,000. This is easily remembered by the formula

$$\frac{PLAN}{33000} = HP.$$

where

P = mean effective pressure per square inch.
L = length of a double stroke in feet.
A = area of piston in square inches.
N = number of revolutions per minute.

Electrical Power

As compared with electrical units the mechanical horse-power equals 746 watts or nearly $\frac{3}{4}$ of a kilowatt, so that a kilowatt (1000 watts) equals 1.34 horse power.

Gas Engine Horse-Power

The A. L. A. M. rating for gasoline engines, which means the rating adopted by the American Licensed Automobile Manufacturers, is based on the assumption that the piston speed is 1000 feet per minute in all cases. This gives 1500 revolutions per minute for a 4-inch stroke motor, which is about average practice. Since the defeat of the Selden patent the A. L. A. M. has ceased to exist and this is now known as the S. A. E. standard (Society of Automotive Engineers).

S. A. E. (A. L. A. M.) HORSE-POWER RATING

THE formula adopted is $\frac{D^2 \times N}{2.5}$ and based on 1000 feet per minute piston speed. D is the cylinder bore, N the number of cylinders, and 2.5 a constant, based on the average view of the Mechanical Branch as to a fair conservative rating.

TABLE OF HORSE-POWER FOR USUAL SIZES OF MOTORS, BASED ON S. A. E. (A. L. A. M.) FORMULA

BORE		HORSE-POWER				
Ins.	M/M	1 Cyl.	2 Cyls.	4 Cyls.	6 Cyls.	8 Cyls.
$2\frac{1}{2}$	64	$2\frac{1}{2}$	5	10	15	20
$2\frac{5}{8}$	68	$2\frac{3}{4}$	$5\frac{1}{2}$	11	$16\frac{1}{2}$	22
$2\frac{3}{4}$	70	3	6	$12\frac{1}{10}$	$18\frac{1}{2}$	$24\frac{2}{10}$
$2\frac{7}{8}$	73	$3\frac{5}{16}$	$6\frac{5}{8}$	$13\frac{1}{4}$	$19\frac{7}{8}$	$26\frac{1}{2}$
3	76	$3\frac{3}{8}$	$7\frac{1}{8}$	$14\frac{2}{5}$	$21\frac{3}{5}$	$28\frac{4}{5}$
$3\frac{1}{8}$	79	$3\frac{15}{16}$	$7\frac{13}{16}$	$15\frac{5}{8}$	$23\frac{7}{16}$	$31\frac{1}{4}$
$3\frac{1}{4}$	83	$4\frac{1}{4}$	$8\frac{1}{2}$	$16\frac{9}{10}$	$25\frac{3}{8}$	$33\frac{8}{10}$
$3\frac{3}{8}$	85	$5\frac{9}{16}$	$9\frac{1}{8}$	$18\frac{1}{4}$	$27\frac{2}{5}$	$36\frac{1}{2}$
$3\frac{1}{2}$	89	$4\frac{9}{10}$	$9\frac{4}{5}$	$19\frac{3}{5}$	$29\frac{2}{5}$	$39\frac{1}{5}$
$3\frac{5}{8}$	92	$5\frac{1}{4}$	$10\frac{1}{2}$	$20\frac{1}{4}$	$31\frac{3}{8}$	$40\frac{1}{2}$
$3\frac{3}{4}$	95	$5\frac{5}{8}$	$11\frac{1}{4}$	$22\frac{1}{2}$	$33\frac{3}{4}$	45
$3\frac{7}{8}$	99	6	12	24	$36\frac{1}{16}$	48
4	102	$6\frac{2}{5}$	$12\frac{1}{5}$	$25\frac{3}{5}$	$38\frac{2}{5}$	$51\frac{1}{5}$
$4\frac{1}{8}$	105	$6\frac{13}{16}$	$13\frac{5}{8}$	$27\frac{1}{4}$	$40\frac{9}{10}$	$54\frac{1}{2}$
$4\frac{1}{4}$	108	$7\frac{1}{4}$	$14\frac{1}{4}$	$28\frac{9}{10}$	$43\frac{1}{5}$	$57\frac{4}{5}$

To simplify reading of the above, the horse-power figures are approximate, but correct within one-sixteenth.

Table of Piston-ring Data

The accompanying table, while not official, is complied with to a great extent in the machinery division of the United States navy yard, Boston, Mass. The sizes run very close to the average make of rings found in the commercial and naval engines of small cylinder bore.

This table is adaptable to ordinary snap rings that are to be rough-turned and bored, cut and drawn together, and finished to the diameter of the cylinder.

TABLE OF PISTON-RING DATA

Diameter of Cylinder, In.	Rough-turn Diameter of Ring, In.	Rough-bore Diameter of Ring, In.	Amount to Cut Out, In.	Width of Ring, In.	Thickness of Ring, In.
2	$2\frac{1}{8}$	$1\frac{13}{16}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$
3	$3\frac{5}{32}$	$2\frac{3}{4}$	$\frac{9}{32}$	$\frac{3}{16}$	$\frac{5}{32}$
4	$4\frac{1}{16}$	$3\frac{5}{8}$	$\frac{7}{16}$	$\frac{1}{4}$	$\frac{3}{16}$
5	$5\frac{7}{32}$	$4\frac{13}{32}$	$\frac{11}{32}$	$\frac{5}{16}$	$\frac{7}{32}$
6	$6\frac{1}{4}$	$5\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{4}$
7	$7\frac{9}{32}$	$6\frac{13}{32}$	$\frac{13}{32}$	$\frac{7}{16}$	$\frac{9}{32}$
8	$8\frac{5}{16}$	$7\frac{9}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{16}$
9	$9\frac{11}{32}$	$8\frac{17}{32}$	$\frac{15}{32}$	$\frac{9}{16}$	$\frac{11}{32}$
10	$10\frac{3}{8}$	$9\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{8}$
12	$12\frac{7}{16}$	$11\frac{7}{16}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{7}{16}$
14	$14\frac{1}{2}$	$13\frac{3}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{2}$
16	$16\frac{9}{16}$	$15\frac{5}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{9}{16}$
18	$18\frac{5}{8}$	$17\frac{1}{4}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{5}{8}$
20	$20\frac{11}{16}$	$19\frac{3}{16}$	1	$\frac{15}{16}$	$\frac{11}{16}$
22	$22\frac{3}{4}$	$20\frac{3}{8}$	$1\frac{1}{8}$	1	$\frac{3}{4}$
24	$24\frac{13}{16}$	$22\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{16}$	$\frac{13}{16}$
30	$30\frac{7}{8}$	28	$1\frac{3}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$
36	$36\frac{15}{16}$	$33\frac{1}{2}$	2	$1\frac{1}{4}$	$1\frac{1}{8}$

This covers general requirements on gasoline and steam engines.

DRIVING POWER OF LEATHER BELTS

THE question of the proper size of a leather belt for a given power transmission resolves itself into a question of selecting various factors. These factors have been worked out by experiments, by analytical methods, and in practice.

The horse-power that a belt will transmit depends upon the effective tension and the belt speed. The effective tension depends upon the difference in the tensions of the two sides of the belt and on the surface friction, which depends upon the ratio of the tensions and the angle of belt contact with pulley.

Experiments and practice have shown that a belt of single thickness will stand a stress of 60 pounds per inch of width and give good results, that is, it will only require an occasional taking up and will have a fairly long life. The corresponding values for double and triple belts are 105 and 150 pounds per inch of width provided the pulleys are not too small.

Experiments have shown that on small pulleys the ratio of the tensions should not exceed 2, on medium pulleys 2.5, and on large pulleys 3. The larger the pulley, the better the contact; also the thinner the belt, the better the contact for the same size of pulley.

When the pulley diameter in *feet* is three times the thickness of the belt in *inches*, or in this proportion, we get equivalent results for different thicknesses of belts. This gives us a method of classifying our pulleys. The belt has to adjust itself in passing over a pulley due to its own thickness. Some adjustment is also necessary on account of the crowning of the pulley. These adjustments account for the different ratios for the various pulley diameters. The effects of the crown and pulley diameter are not usually considered in belt rules, although they should be. The ratios given are for 180 degrees wrap and decrease with less contact.

The creep of the belt depends upon its elasticity and the load, and experiments have shown that this should not exceed 1 per cent. in good practice. In order to keep this creep below 1 per cent. it is necessary to limit the difference of tension per inch of width of single belt to 40 pounds. The corresponding values for double and triple belts are 70 and 100 pounds per inch of width. These figures are based on an average value of 20,000 for the running modulus of elasticity of leather belting.

Table I has been prepared on the basis of these limitations and gives a value for the factor or constant F in the equation

$$H.P. = \frac{V \times W}{F} \text{ or } W = \frac{H.P. \times F}{V}$$

in which $H\ P$ is the horse-power, V the belt velocity in feet per minute, and W the width in inches.

Table II gives corrected values for F, when the arc of contact or wrap is greater or less than 180 degrees. On large pulleys the creep may exceed 1 per cent. if the wrap is over 180 degrees, as the increased friction gives a greater difference of tensions.

To illustrate the use of the tables, we will take the following examples:

TABLE I.—FACTORS FOR 180 DEGREES OF BELT CONTACT

Diameter of pulley	Under 8″	8″–36″	Over 3 feet	Under 14″	14″–60″	Over 5 feet	Under 21″	21″–84″	Over 7 feet
Thickness of belt	Single	Single	Single	Double	Double	Double	Triple	Triple	Triple
Factor	1100	920	830	630	520	470	440	370	330
Difference of tensions	30	36	40	52.5	63	70	75	90	100
Per cent. of creep	0.74	0.89	0.99	0.74	0.89	0.99	0.74	0.89	0.99
Ratio of tensions	2.00	2.50	3.00	2.00	2.50	3.00	2.00	2.50	3.00
Tension on tight side	60	60	60	105	105	105	150	150	150

TABLE II.—FACTORS FOR VARYING DEGREES OF BELT CONTACT

220°	210°	200°	190°	180°	170°	160°	150°	140°	130°	120°
980	1010	1040	1070	1100	1140	1180	1220	1270	1330	1400
810	830	860	890	920	950	990	1040	1100	1170	1240
730	750	770	800	830	860	890	930	980	1030	1100
560	570	590	610	630	650	670	700	730	760	800
460	470	480	500	520	540	570	600	630	660	700
420	430	440	450	470	490	510	530	560	590	630
390	400	410	420	440	460	480	500	520	540	560
320	330	340	350	370	390	410	430	450	470	490
290	300	310	320	330	340	360	380	400	420	440

How much horse-power will a 4-inch single belt transmit at a speed of 4,600 feet per minute passing over a 12-inch pulley? The factor is 920, therefore,

$$\frac{4{,}600 \times 4}{920} = 20 \text{ H.-P.}$$

How wide should a belt be in order to transmit 50 horse-power at 2,000 feet per minute on a 36-inch pulley?

$$W = \frac{50 \times 830}{2{,}000} = 20.7 \text{ inch single belt.}$$

This gives a width of single belt beyond the usual limit, 8 inches being considered good practice for the maximum width of a single belt.

$$W = \frac{50 \times 520}{2{,}000} = 13\text{-inch double belt.}$$

How wide should a single belt be in order to transmit 2 horse-power at 600 feet per minute over a 4-inch pulley with 140-degree wrap?

In this case we take the factor 1,100 from Table 1 and in Table 2 find a corrected value for 1,100 under 140 degrees of 1,270.

$$W = \frac{2 \times 1{,}270}{600} = 4.23\text{-inch single belt.}$$

How wide a belt is required for 300 horse-power at 2,000 feet per minute over a 10-foot pulley?

$$W = \frac{300 \times 470}{2{,}000} = 70.5\text{-inch double belt.}$$

This is too wide. Good practice calls for a change to triple at 48 inches unless for some special reason a narrower belt is necessary.

$$W = \frac{300 \times 330}{2{,}000} = 49.5\text{-inch triple belt.}$$

The results given by these factors are well within working values and the belts will probably transmit 50 per cent. more power than these factors, but at the expense of the life of the belt. A liberal allowance at the beginning means less annoyance, fewer delays in taking up the belts, longer life and less cost for renewals and repairs. Belt speeds of 4,000 to 4,800 feet should rarely be exceeded.

A simple formula for computing the arc of contact is:

$$\text{Arc} = 180 - 60\frac{D - d}{e}$$

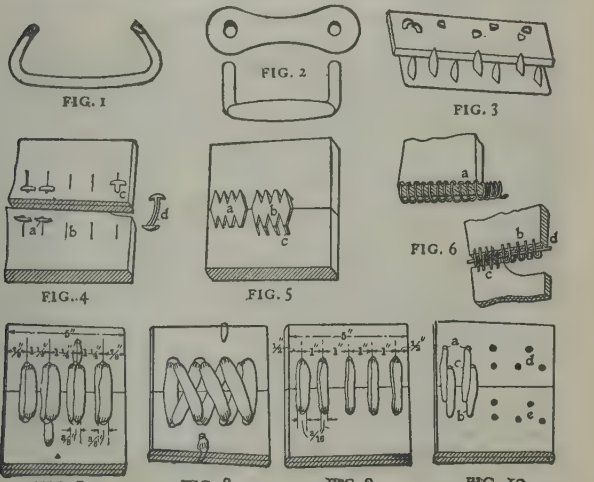
in which D = diameter of large pulley; d = diameter of small pulley; e = distance center to center. For crossed belts change the minus sign between D and d to plus.

BELT FASTENINGS

The best fastening for a belt is the cement splice. It is far beyond any form of lacing, belt hooks, riveting, or any other method of joining together the ends of a belt. The cement joint is easily applied to leather and to rubber belts, but to make a good cement splice in a canvas belt requires more time and apparatus than is usually at hand. Good glue makes a fine cement for leather belts, and fish glue is less affected by moisture than the other. Many of the liquid glues are fish glue treated with acid so as not to gelatinize when cold. A little bichromate of pot ashadded to ordinary hot glue just before it is used will render it insoluble in water. Both lap and wedge joints are used.

Belt Hooks

There are many styles of belt hooks in use, some of the more common kinds being shown in Figs. 1, 2, 3 and 4. Fig. 2 is practically a double rivet, Fig. 3 a malleable iron fastening, although



Belt Hooks and Lacings

similar hooks have been made of pressed steel, and Fig. 4 is the Blake stud, which has the advantage of not weakening the belt but makes a hump on the outside where the ends turn up. Fig. 5 is the Bristol hook of stamped steel which is driven in and the points turned over on the other side. Fig. 6 is the Jackson belt lacing and is

applied by a hand machine which screws a spiral wire across the ends of a belt. These are then flattened and a rawhide pin or a heavy soft cord used as a hinge joint between them. These joints are probably equal to 90 per cent. of the belt strength.

Lacing Belts

Belts fastened by lacing are weakened according to the amount of material punched out in making the holes to receive the lacing. It is preferable to lace with a small lacing put many times through small holes. Such a joint is stronger than a few pieces of wide lacing through a number of large holes. Figs. 7 and 9 illustrate two forms of belt lacing, the latter being far preferable to the other. The lacing shown by Fig. 7 is in a double leather belt 5 inches wide. The width makes no difference as the strength is figured in percentage of the total width. There are four holes in this piece of belt, each hole $\frac{3}{8}$ inch in diameter. The aggregate width thus cut out of the belt is $4 \times \frac{3}{8}$ inch $= 1\frac{2}{8} = 1\frac{1}{2}$ inches. Then $1.5 \div 5 = 0.30$, or 30 per cent. of the belt has been cut away—nearly one-third of the total strength.

Another Method of Lacing

In Fig. 9 a different method is followed. Instead of there being a few large holes, there are more smaller ones—one-fourth more, in fact. There are five holes, each $\frac{7}{16}$ inch in diameter, making a total of $\frac{5}{16}$ inch or $0.9375 \times 5 = 18\frac{3}{4}$ per cent. leaving $81\frac{1}{4}$ per cent. of the total belt strength against 70 per cent. in the belt with large holes. A first-class double leather belt will tear in two under a strain of about 500 pounds to each lace hole, the strain being applied in the holes by means of lacings.

The belt shown by Fig. 9 has $81\frac{1}{4}$ per cent. of 1.875 square inches of section, $= 1.525$ square inches left after cutting out the five holes. This amount is good for $3000 \times 1.875 = 5625$ pounds breaking strain, and as the lacing will tear out under 2500 pounds, it will be seen that we cannot afford to use lacings if the full power of the leather is to be utilized. This, under a factor of safety of 5, would be 1125 pounds to the square inch, or $1125 \times 1.525 = 1715$ pounds working strain for the belt, or $1715 \div 5 = 343.5$ pounds to each lace. This, too, is too much, as it is less than a factor of safety of 2.

The belt to carry 40 pounds working tension to the inch of width must also carry about 40 pounds standing tension, making a strain of 80 pounds to the inch, or $80 \times 5 = 400$ pounds. This is a better showing, and gives a factor of safety of $2500 \div 400 = 6\frac{1}{4}$. Still, we are wasting a belt of 5625 pounds ultimate strength in order to get from it 400 pounds working strain. This means a factor of safety of over 14 in the body of the belt but of only $6\frac{1}{4}$ at the lacing, which shows the advantage of a cement splice.

Fig. 10 shows a method sometimes used to relieve the lace-holes of some of the strain. Double rows of holes are punched as at *a b*, and the lacing distributed among them. As far as helping the strength of the belt is concerned, this does nothing, for all the stress put upon the belt by the lacing at *c* must be carried by the belt section at *a*; therefore this way of punching holes does not increase the

section strength. Neither does staggering the holes as shown at *d* and *e*. The form of hole-punching shown at *a b c* is desirable for another reason. It distributes the lacing very nicely and does not make such a lump to thump when it passes over the pulleys.

ALIGNING SHAFTING BY A STEEL WIRE

A STEEL wire is often used for aligning shafting by stretching it parallel with the direction of the shaft and measuring from the shaft to the wire in a horizontal direction. This steel wire can also be used for leveling or aligning in a direction at right angles to the other,

SAGS OF A STEEL ALIGNING WIRE FOR SHAFTING

Distance in Feet, from Reel to Point of Measurement

Distance in Feet, from Reel to Point of Support

Sag of the Wire in Inches

	10	20	30	40	50	60	70	80	90	100	110	120	130	140
280	1/4	31/64	11/16	57/64	1 1/16	1 7/32	1 63/64	1 31/64	1 27/32	2 43/64	2 47/64	2 25/32	2 13/16	2 53/64
270	15/64	15/32	43/64	55/64	1 3/32	1 13/64	1 61/64	1 29/64	1 27/32	2 37/64	2 41/64	2 23/32	2 25/32	2 51/64
260	15/64	29/64	21/32	27/32	1 1/16	1 13/64	1 59/64	1 29/64	1 27/32	2 31/64	2 35/64	2 11/16	2 25/32	2 49/64
250	7/32	27/64	39/64	25/32	1 1/32	1 13/64	1 57/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
240	7/32	13/32	37/64	49/64	1	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
230	13/64	25/64	9/16	47/64	63/64	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
220	13/64	25/64	35/64	23/32	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
210	11/64	11/32	17/32	45/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
200	11/64	21/64	33/64	43/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
190	5/32	5/16	1/2	41/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
180	5/32	19/64	31/64	5/8	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
170	9/64	9/32	15/32	39/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
160	9/64	17/64	29/64	19/32	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
150	1/8	1/4	7/16	37/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
140	7/64	15/64	27/64	35/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
130	3/32	13/64	25/64	33/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
120	3/32	11/64	23/64	31/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
110	3/32	5/32	11/64	29/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
100	3/32	9/64	1/8	27/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
90	5/64	1/8	7/64	1/4	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
80	1/16	7/64	3/32	9/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
70	1/64	1/32	3/64	1/16	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
60		1/64	1/32	3/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
50			1/64	1/32	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
40				1/64	31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64
30					31/32	1 13/64	1 55/64	1 29/64	1 27/32	2 29/64	2 33/64	2 11/16	2 23/32	2 47/64

by making vertical measurements, if it is stretched under established conditions and if the sags at the points of measurement are known. The accompanying table gives the sags in inches from a

truly level line passing through the points of support of the wire, at successive points beginning 10 feet from the reel and spaced 10 feet apart for a No. 17 Birmingham gage high grade piano wire, stretched with a weight of 60 pounds, wound on a reel of a minimum diameter of three and one-half inches and for total distances between the reel and point of support of the wire varying by increments of 10 feet from 40 to 280 feet. Thus a wire of any convenient length, of the kind indicated, can be selected, so long as this length is a multiple of 10 feet and between the limits specified, and the table gives the sags from a truly level line at points 10 feet apart for its entire length when it is stretched under the conditions designated. These sags being known, direct measurements can be made to level or align a shaft by vertical measurements.

The method was originally developed for alining the propeller shafts of vessels, but it is equally serviceable for semi-flexible shafting, as factory line shafts.

Speed of Shafting

Line shaft speed varies with machinery it drives. Probably 250 r.p.m. is an average today, with cases of 400 r.p.m. even on 4-in. shafts and 600 to 700 r.p.m. on 2-in. shafts for high speed machinery.

HORSE POWER OF STEEL SHAFTING

For Line Shaft Service

Shaft Sizes Inches	Revolutions per Minute										Max. Dist. Between Bearings
	100	125	150	175	200	225	250	300	350	400	
1 3/16	2.4	3.1	3.7	4.3	4.9	5.5	6.1	7.3	8.5	9.7	....
1 1/8	4.3	5.3	6.4	7.4	8.5	9.5	10.5	12.7	14.8	16.9	6.8″
1 1/4	6.7	8.4	10.1	11.7	13.4	15.1	16.7	20.1	23.4	26.8	7.2″
1 3/8	10.0	12.5	15.0	17.5	20.0	22.5	25.0	30.0	35.0	40.0	8.2″
1 7/16	14.3	17.8	21.4	24.9	28.5	32.1	35.6	42.7	49.8	57.0	8.9″
1 7/8	19.5	24.4	29.3	34.1	39.0	44.1	48.7	58.5	68.2	78.0	9.6″
2 1/16	26.0	32.5	39.0	43.5	52.0	58.5	65.0	78.0	87.0	104.0	10.2″
2 1/8	33.8	42.2	50.6	59.1	67.5	75.9	84.4	101.3	118.2	135.0	10.8″
2 3/16	43.0	53.6	64.4	75.1	85.8	96.6	107.3	128.7	150.3	171.6	11.4″
2 7/16	53.6	67.0	79.4	93.8	107.2	120.1	134.0	158.8	187.6	214.4	12.0″
2 1/2	65.9	82.4	97.9	115.4	121.8	148.3	164.8	195.7	230.7	243.6	12.5″
2 5/8	80.0	100.0	120.0	140.0	160.0	180.0	200.0	240.0	280.0	320.0	....
2 7/8	113.9	142.4	170.8	199.3	227.8	256.2	284.7	341.7	398.6	455.6	....
3 1/16	156.3	195.3	234.4	273.4	312.5	351.5	390.6	468.7	546.8	625.0	....
3 1/2	207.0	260.0	311.9	363.9	415.9	459.9	520.0	623.9	727.9	830.0	....
6	270.0	337.5	405.0	472.5	540.0	607.5	675.0	810.0	945.0	1080.0	....
6 1/2	343.3	429.0	514.9	600.7	686.5	772.4	858.0	1029.0	1201.0	1372.0	....
7	428.8	535.9	643.1	750.3	847.5	964.7	1071.9	1286.0	1500.0	1695.0	....
8	640.0	800.0	960.0	1126.0	1280.0	1440.0	1600.9	1920.0	2240.0	2560.0	....

This table is based on the formula

$$M = \frac{D^3 \times R}{80}.$$ For heavier work use $$M = \frac{D^3 \times R}{100}$$

For head and jack shafts, supported by bearings close to main sheave or pulley so as to prevent transverse strain, the following formula may be used with safety:

$$M = \frac{D^3 \times R}{125}$$

D = Diameter of shaft in inches.
R = Number of revolutions per minute.
M = Horse-power.

Deflection of shafting from weight of pulleys and pull of belting should not be allowed in excess of .001 per foot, as this action adds very rapidly to the power cost. If this deflection is at a clutch, sleeve or roller bearing, any of them may be ruined easily and quickly. It can be reduced by using more hangers.

SPEEDS OF PULLEYS AND GEARS

THE fact that the circumference of a pulley or gear is always 3.1416 or $3\frac{1}{7}$ times the diameter makes it easy to figure speeds by considering only the diameter of both driver and driven pulleys. Belting from one 6-inch pulley to another gives the same speed to both; but if the driving pulley is 16 inches and the driven pulley only 4 inches it is clear that the small pulley will turn 4 times for every turn of the large pulley. If this is reversed and the small pulley is the driver, the large pulley will only make one turn for every four of the small pulley. The same rule applies to gears if the *pitch diameter* and not the outside diameter is taken. The following rules have been arranged for convenience in finding any desired information about pulley or gear speeds.

HAVING	TO FIND	RULE
Diameter of Driving Pulley Diameter of Driven Pulley Speed of Driving Pulley	Speed of Driven Pulley	Multiply Diameter of Driving Pulley by its Speed and divide by Diameter of Driven Pulley.
Diameter of Driving Pulley Speed of Driving Pulley Speed of Driven Pulley	Diameter of Driven Pulley	Multiply Diameter of Driving Pulley by its Speed and Divide by Speed of Driven Pulley.
Diameter of Driving Pulley Diameter of Driven Pulley Speed of Driven Pulley	Speed of Driving Pulley	Multiply Diameter of Driven Pulley by its Speed and Divide by Diameter of Driving Pulley.
Diameter of Driven Pulley Speed of Driven Pulley Speed of Driving Pulley	Diameter of Driving Pulley	Multiply Diameter of Driven Pulley by its Speed and Divide by Speed of Driving Pulley.

Circumferential Speeds in Feet per Minute

(*See page* 668)

Diameter in Inches	Revolutions per Minute										
	50	100	150	200	250	300	350	400	450	500	550
1	13	26	39	52	65	79	92	105	118	131	144
2	26	52	79	105	131	157	183	209	236	262	288
3	39	79	118	157	196	236	275	314	353	393	432
4	52	105	157	209	262	314	367	419	471	523	576
5	65	131	196	262	328	393	458	524	589	654	720
6	79	157	236	314	393	471	550	628	707	785	863
7	92	183	275	367	458	550	641	733	825	916	1,008
8	105	209	314	419	524	628	733	838	942	1,047	1,152
9	118	236	353	471	589	707	825	942	1,060	1,178	1,296
10	131	262	393	524	655	785	916	1,047	1,178	1,309	1,440
11	144	288	432	576	720	864	1008	1,152	1,296	1,440	1,584
12	157	314	471	628	785	943	1100	1,257	1,414	1,571	1,728
13	170	340	511	681	851	1021	1191	1,361	1,532	1,701	1,872
14	183	367	550	733	916	1100	1283	1,466	1,649	1,832	2,016
15	196	393	589	785	982	1178	1375	1,571	1,767	1,963	2,160
16	209	419	628	838	1047	1257	1466	1,675	1,885	2,094	2,304
17	223	445	668	890	1113	1335	1558	1,780	2,003	2,225	2,442
18	236	471	707	943	1178	1414	1649	1,885	2,121	2,356	2,592
19	249	497	746	995	1244	1492	1741	1,990	2,238	2,487	2,736
20	262	524	785	1047	1309	1571	1833	2,094	2,356	2,618	2,880
21	275	550	825	1100	1374	1649	1924	2,199	2,474	2,749	3,024
22	288	576	864	1152	1440	1728	2016	2,304	2,592	2,880	3,168
23	301	602	903	1204	1505	1806	2107	2,409	2,710	3,011	3,312
24	314	628	943	1257	1571	1885	2199	2,513	2,827	3,142	3,456
25	327	655	982	1309	1636	1963	2291	2,618	2,945	3,273	3,000
26	340	681	1021	1361	1702	2042	2382	2,723	3,063	3,403	3,744
27	353	707	1060	1414	1767	2121	2474	2,827	3,181	3,534	3,888
28	367	733	1100	1466	1837	2199	2566	2,932	3,299	3,665	4,032
29	380	759	1139	1518	1898	2278	2657	3,037	3,417	3,796	4,176
30	393	785	1178	1571	1964	2356	2749	3,142	3,534	3,927	4,320
31	406	812	1217	1623	2029	2435	2840	3,246	3,652	4,058	4,464
32	419	838	1257	1676	2094	2513	2932	3,351	3,770	4,189	4,608
33	432	864	1296	1728	2160	2592	3024	3,456	3,888	4,320	4,752
34	445	890	1335	1780	2225	2670	3115	3,560	4,006	4,451	4,896
35	458	916	1375	1833	2291	2749	3206	3,665	4,123	4,581	5,040
36	471	943	1414	1885	2356	2827	3299	3,770	4,241	4,712	5,184
37	484	969	1453	1937	2422	2906	3390	3,875	4,359	4,843	5,328
38	497	995	1492	1990	2487	2985	3482	3,979	4,477	4,974	5,472
39	511	1021	1532	2042	2553	3063	3573	4,084	4,595	5,105	5,616
40	524	1047	1571	2094	2618	3142	3665	4,189	4,712	5,236	5,760
41	537	1073	1610	2147	2683	3220	3757	4,294	4,831	5,367	5,904
42	550	1100	1649	2199	2749	3299	3848	4,398	4,948	5,498	6,048
43	563	1126	1689	2251	2814	3377	3940	4,503	5,066	5,629	6,192
44	576	1152	1728	2304	2880	3456	4032	4,608	5,184	5,760	6,336
45	589	1178	1767	2356	2945	3534	4123	4,712	5,301	5,891	6,480
46	602	1204	1806	2408	3011	3613	4215	4,817	5,419	6,021	6,623
47	615	1231	1846	2461	3076	3692	4307	4,922	5,537	6,152	6,768
48	628	1257	1885	2513	3142	3770	4398	5,027	5,655	6,283	6,912
49	641	1283	1924	2566	3207	3849	4490	5,131	5,773	6,414	7,056
50	655	1309	1963	2618	3273	3927	4581	5,236	5,891	6,545	7,200

Circumferential Speeds in Feet per Minute

(*See page* 668)

Diameter in Inches	Revolutions per Minute										
	50	100	150	200	250	300	350	400	450	500	550
51	668	1335	2003	2670	3338	4006	4673	5,341	6,008	6,676	7,343
52	681	1361	2042	2723	3403	4084	4764	5,445	6,126	6,807	7,487
53	694	1388	2081	2775	3469	4163	4856	5,550	6,244	6,938	7,631
54	707	1414	2121	2827	3534	4241	4948	5,655	6,362	7,069	7,775
55	720	1440	2160	2880	3600	4320	5040	5,760	6,480	7,199	7,919
56	733	1466	2199	2932	3665	4398	5131	5,864	6,597	7,330	8,063
57	746	1492	2238	2985	3731	4477	5223	5,969	6,715	7,461	8,207
58	759	1518	2278	3037	3796	4555	5314	6,074	6,833	7,592	8,351
59	772	1545	2317	3089	3862	4634	5406	6,178	6,951	7,723	8,495
60	785	1571	2356	3142	3927	4712	5498	6,283	7,069	7,854	8,639
61	799	1597	2395	3194	3992	4791	5589	6,388	7,186	7,985	8,783
62	812	1623	2435	3246	4058	4870	5681	6,493	7,304	8,116	8,927
63	825	1649	2474	3299	4123	4948	5773	6,597	7,422	8,247	9,071
64	838	1676	2513	3351	4189	5027	5864	6,702	7,540	8,378	9,215
65	851	1702	2552	3403	4254	5105	5956	6,807	7,658	8,508	9,359
66	864	1728	2592	3456	4320	5184	6048	6,912	7,775	8,640	9,503
67	877	1754	2631	3508	4385	5262	6139	7,016	7,893	8,770	9,647
68	890	1780	2670	3560	4451	5341	6231	7,121	8,011	8,901	9,791
69	903	1806	2710	3613	4516	5419	6322	7,226	8,129	9,032	9,935
70	916	1833	2749	3665	4581	5498	6414	7,330	8,247	9,163	10,079
71	929	1859	2788	3718	4647	5576	6506	7,435	8,365	9,294	10,223
72	943	1885	2827	3770	4712	5655	6597	7,540	8,482	9,425	10,367
73	956	1911	2867	3822	4778	5733	6689	7,644	8,600	9,556	10,511
74	969	1937	2906	3875	4843	5812	6781	7,749	8,718	9,687	10,655
75	982	1964	2945	3927	4909	5890	6872	7,854	8,836	9,818	10,796
76	995	1990	2985	3979	4974	5969	6964	7,959	8,954	9,948	10,943
77	1008	2016	3024	4032	5040	6048	7056	8,063	9,072	10,079	11,087
78	1021	2042	3063	4084	5105	6126	7147	8,168	9,189	10,210	11,231
79	1034	2068	3102	4136	5171	6205	7239	8,273	9,307	10,341	11,375
80	1047	2094	3142	4189	5236	6283	7330	8,378	9,425	10,472	11,519
81	1060	2121	3181	4241	5301	6362	7422	8,482	9,543	10,603	11,663
82	1073	2147	3220	4294	5367	6440	7514	8,587	9,660	10,734	11,807
83	1087	2173	3259	4346	5432	6519	7605	8,692	9,778	10,865	11,951
84	1100	2199	3299	4398	5498	6597	7697	8,797	9,896	10,996	12,099
85	1113	2225	3338	4451	5563	6676	7789	8,901	10,014	11,127	12,235
86	1126	2251	3377	4503	5629	6754	7880	9,006	10,132	11,257	12,383
87	1139	2278	3417	4555	5694	6833	7972	9,111	10,249	11,388	12,527
88	1152	2304	3456	4607	5760	6912	8063	9,215	10,367	11,519	
89	1161	2330	3495	4660	5825	6990	8155	9,320	10,485	11,650	
90	1178	2356	3534	4712	5891	7069	8247	9,425	10,603	11,780	
91	1191	2382	3574	4765	5956	7147	8338	9,530	10,721	11,912	
92	1204	2408	3613	4817	6021	7226	8430	9,634	10,839	12,043	
93	1217	2435	3652	4870	6087	7304	8522	9,739	10,956	12,174	
94	1231	2461	3692	4922	6152	7383	8613	9,844	11,074	12,305	
95	1244	2487	3731	4974	6217	7461	8704	9,948	11,192	12,436	
96	1257	2513	3770	5027	6283	7540	8796	10,053	11,310	12,566	
97	1270	2539	3809	5079	6349	7618	8888	10,158	11,428		
98	1283	2566	3849	5131	6414	7697	8980	10,263	11,545		
99	1296	2592	3888	5183	6480	7775	9071	10,367	11,663		
100	1309	2618	3927	5236	6545	7854	9163	10,472	11,781		

Circumferential Speeds in Feet per Minute

Revolutions per Minute

Diameter in Inches			2,400	2,600	2,800	3,000	3,200	3,400	3,600	3,800	4,000	4,400
			1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000	2,200
			600	650	700	750	800	850	900	950	1,000	1,100
¼	½	1	157	170	183	196	209	223	236	249	262	288
½	1	2	314	340	367	393	419	445	471	497	524	576
¾	1½	3	471	510	550	589	628	668	707	746	785	863
1	2	4	628	681	733	785	838	890	942	995	1,047	1,152
1¼	2½	5	785	851	916	982	1,047	1,113	1,178	1,244	1,309	1,440
1½	3	6	942	1,021	1,100	1,178	1,257	1,335	1,414	1,492	1,571	1,728
1¾	3½	7	1,100	1,191	1,283	1,375	1,466	1,558	1,649	1,741	1,832	2,016
2	4	8	1,257	1,361	1,466	1,571	1,675	1,780	1,885	1,990	2,094	2,304
2¼	4½	9	1,414	1,531	1,649	1,767	1,885	2,003	2,121	2,238	2,356	2,592
2½	5	10	1,571	1,702	1,833	1,964	2,094	2,225	2,356	2,487	2,618	2,880
2¾	5½	11	1,728	1,872	2,016	2,160	2,304	2,448	2,592	2,736	2,880	3,168
3	6	12	1,885	2,042	2,199	2,356	2,513	2,670	2,827	2,984	3,143	3,456
3¼	6½	13	2,042	2,212	2,382	2,552	2,723	2,893	3,063	3,233	3,403	3,744
3½	7	14	2,199	2,382	2,566	2,749	2,932	3,115	3,299	3,482	3,665	4,032
3¾	7½	15	2,356	2,552	2,749	2,945	3,142	3,338	3,534	3,731	3,927	4,320
4	8	16	2,513	2,723	2,932	3,142	3,351	3,560	3,770	3,979	4,189	4,608
4¼	8½	17	2,670	2,893	3,115	3,338	3,560	3,783	4,006	4,228	4,451	4,896
4½	9	18	2,827	3,063	3,299	3,534	3,770	4,006	4,241	4,477	4,712	5,184
4¾	9½	19	2,985	3,233	3,482	3,731	3,979	4,228	4,477	4,725	4,974	5,472
5	10	20	3,142	3,403	3,665	3,927	4,189	4,451	4,712	4,974	5,236	5,760
5¼	10½	21	3,299	3,573	3,848	4,123	4,398	4,673	4,948	5,223	5,498	6,048
5½	11	22	3,456	3,744	4,032	4,320	4,608	4,896	5,184	5,472	5,760	6,336
5¾	11½	23	3,613	3,914	4,215	4,516	4,817	5,118	5,419	5,720	6,021	6,623

Diameter in Inches													
6	12	24	3,770	4,084	4,398	4,712	5,027	5,341	5,655	5,969	6,283	6,912
6½	12½	25	3,927	4,254	4,581	4,909	5,236	5,563	5,891	6,218	6,545	7,200
6½	13	26	4,084	4,424	4,764	5,105	5,445	5,786	6,126	6,466	6,807	7,487
6¾	13½	27	4,241	4,594	4,948	5,301	5,655	6,008	6,362	6,715	7,069	7,775
7	14	28	4,398	4,764	5,131	5,498	5,864	6,231	6,597	6,963	7,330	8,063
7¼	14½	29	4,555	4,935	5,314	5,694	6,074	6,453	6,833	7,213	7,592	8,351
7½	15	30	4,712	5,105	5,498	5,890	6,283	6,676	7,069	7,461	7,854	8,639
7¾	15½	31	4,870	5,275	5,681	6,086	6,493	6,988	7,304	7,710	8,116	8,927
8	16	32	5,027	5,445	5,864	6,283	6,702	7,121	7,540	7,959	8,378	9,215
8¼	16½	33	5,184	5,615	6,048	6,479	6,912	7,343	7,775	8,207	8,640	9,503
8½	17	34	5,341	5,785	6,231	6,676	7,121	7,566	8,011	8,456	8,901	9,791
8¾	17½	35	5,498	5,956	6,414	6,872	7,330	7,789	8,247	8,705	9,163	10,079
9	18	36	5,655	6,126	6,597	7,069	7,540	8,011	8,482	8,954	9,425	10,367
9¼	18½	37	5,812	6,296	6,781	7,265	7,749	8,234	8,718	9,202	9,687	10,655
9½	19	38	5,969	6,466	6,964	7,461	7,959	8,456	8,954	9,451	9,948	10,943
9¾	19½	39	6,126	6,637	7,147	7,658	8,168	8,679	9,189	9,700	10,210	
10	20	40	6,283	6,807	7,330	7,854	8,378	8,901	9,425	9,948	10,472	
10¼	20½	41	6,440	6,977	7,514	8,050	8,587	9,124	9,660	10,197	10,734	
10½	21	42	6,597	7,147	7,697	8,247	8,797	9,346	9,896	10,446	10,996	
10¾	21½	43	6,754	7,317	7,880	8,443	9,006	9,569	10,131	10,695		
11	22	44	6,912	7,487	8,063	8,639	9,215	9,791	10,367	10,943		
11¼	22½	45	7,069	7,658	8,247	8,836	9,425	10,014	10,603			
11½	23	46	7,226	7,828	8,430	9,032	9,634	10,236	10,839			
11¾	23½	47	7,383	7,998	8,613	9,228	9,844	10,459				
12	24	48	7,540	8,168	8,797	9,425	10,053	10,681				
12¼	24½	49	7,697	8,338	8,980	9,621	10,263	10,903				
12½	25	50	7,854	8,508	9,163	9,818	10,472					
12¾	25½	51	8,011	8,679	9,346	10,014	10,681					
13	26	52	8,168	8,849	9,529	10,210	10,891					
13¼	26½	53	8,325	9,019	9,712	10,407						
13½	27	54	8,482	9,189	9,896	10,603						
13¾	27½	55	8,639	9,359	10,079	10,799						
14	28	56	8,797	9,530	10,263	10,996						
14¼	28½	57	8,954	9,700	10,446							
14½	29	58	9,111	9,870	10,629							
14¾	29½	59	9,268	10,040	10,812							
15	30	60	9,425	10,210	10,996							

Revolutions per Minute

Diameter				2,400	2,600
				1,200	1,300
				600	650
	15½	30½	61	9,582	10,380
	15⅝	31	62	9,739	10,551
	15¾	31½	63	9,896	10,721
	16	32	64	10,053	10,891
	16¼	32½	65	10,210	
	16½	33	66	10,367	
	16¾	33½	67	10,524	
	17	34	68	10,681	
	17½	34½	69	10,839	

The rules on page 663 apply equally well to a number of pulley belts together or to a train of gears if *all* the driving and *all* the driven pulley diameters and speeds are grouped together.

TABLES OF CIRCUMFERENTIAL SPEEDS

THE tables on pages 664–667 which give circumferential speeds, can be used for obtaining gear and belt speeds and the speed of revolving parts of high-speed motors.

For diameters greater than those given in the tables, the speeds can be obtained by adding together the speeds for two diameters whose sum equals that of the diameter for which we require the speed. For example, to find the speed at a 120-inch diameter and 200 revolutions per minute, the following calculation is readily made:

Speed for 100-inch diameter—5236 feet.
Speed for 20-inch diameter—1047 feet.
Speed for 120-inch diameter—6283 feet.

To interpolate, we can use the values given for speed for 1- to 10-inch diameters, dividing them by 10, 100, 1000, etc., to obtain speeds for tenths, hundredths, thousandths, etc. For instance, if the speed for 550 revolutions per minute and 46.186-inch diameter is required, we proceed as follows:

For 46 in. diameter.....speed = 6623 ft.
For 0.1 in. diameter = $\frac{1}{10}$ of 1-in. diameter speed = 14.4 ft.
For 0.08 in. diameter = $\frac{8}{100}$ of 8-in. diameter speed = 11.5 ft.
For 0.006 in. diameter = $\frac{6}{1000}$ of 6-in. diameter speed = 0.9 ft.
For 46.186 in. diameter.....speed = 6650 ft.

POWER REQUIRED BY MACHINE TOOLS

Engine Lathes

Swing, Inches	Horse-power Average Work	Heavy Work
12	½	2
14	¾ – 1	2 – 3
16	1 – 2	2 – 3
18	2 – 3	3 – 5
20–22	3	7½–10
24–27	5	7½–10
30	5 – 7½	7½–10
32–36	7½–10	10 –15
38–42	15 –20	20 –25
48–54	20 –25	25 –30
60–84	25 –30	30 –35

Axle Lathes

	Horse-power
Single	5– 7½ 10
Double	10–15 –20
Locomotive axle	25

Wheel Lathes

	Horse-power Tailstock	Motor
48-inch car wheel	15–20	5
51–60 driving wheel	15–20	5
79–84	25–30	5
90	30–40	5–7½
100	40–50	5–7½
Quartering attachment	3– 5	

Vertical Boring Mills

Size,	Horse-power Average	Heavy
36–42 inches	5 – 7½	7½–10
50 inches	7½	7½–10
60–84 inches	7½–10	10 –15
7–12 feet	10 –15	30 –40
14–25 feet	15 –25	30 –40

Horizontal Boring, Drilling and Milling Machine

Diam. Spindle	Horse-power for Single Spindle
3½–4½	5 – 7½
4½–5½	7½–10
5½–6½	10 –15

For double spindle, use double the horse-power.

Cylinder Boring Mach.

Diam. Spindle	Max. Boring Diameter	Horse-power
4	20	7½
6	30	10
8	40	15

Miscellaneous

	Horse-power
Locomotive rod-boring machine	7½–10
Car-box boring machine	
6 x 12 and 5½ x 10" boxes	5 – 7½
Car-wheel borer	10 –15

Planers

Size, Inches	Horse-power
24 x 24	3– 5
30 x 30	5– 7½
36 x 36	10–15
48 x 48	15–20
60 x 60	20–25
72 x 72	25–35
84 x 84	25–35
100 x 100	35–50

Note.—Normal length of table in feet is about one-fourth the width in inches.

Frog and Switch Planers

Inches	Horse-power
36 x 12	30
48 x 36	30

Rotary Planers

Diam. Cutter, Inches	Horse-power
24– 30	5– 7½
36– 42	10
48 –54	15
60– 72	20–25
84–100	30–40

Shapers

	Horse-power
12–16-inch stroke	2
18-inch stroke	2– 3
20–24-inch stroke	3– 5
30-inch stroke	5– 7½
20-inch Traverse-head	7½
24-inch Traverse-head	10

Crank Slotters

Stroke	Horse-power
6– 8	3 – 5
10–12	5
14	5 – 7½
16–18	7½–10
20–30	10 –20

Plain Millers

Table-feed	Cross-feed	Horse-power
34	10	7½
42	12	10
50	12	15

Universal Millers

	Horse-power
Nos. 1–1½	1 – 2
No. 2	3 – 5
No. 3	5 – 7½
No. 4	7½–10
No. 5	10 –15

Vertical Millers

Height under Work, Inches	Horse-power
12–14	5– 7½
18	10
20	15
24	20

Horizontal Slab Millers

Width between Housings, Inches	Horse-power	
	Average	Heavy
24–30	7½–10	10–15
36	10 –15	20–25
60–72	25	75

Cylindrical Grinders

Diam. Wheel	Horse-power	
	Average	Heavy
10 in.	5	7½
14 in.	10	15
18 in.	10	15

Grinding Stands

No. Wheels	Diam., Inches	Horse-power
2	6	½– 1
2	10	2
2	12	3
2	18	5 – 7½
2	24–26	7½–10

Miscellaneous Grinders

Type	Horse-power
Wet tool	2–3
Flexible swing	3
Angle cock	3
Piston rod	3
Twist drill	2
Automatic tool	3–5
Car wheel	30

Buffing Heads

No. Wheels	Diam.	Horse-Power
2	6	¼– ½
2	10	1 –2
2	14	3 –5

Vertical Drills

Size, Inches	Horse-power
12–20	1
24–28	2
30–32	3
36–40	5
50–60	5 –7½
Sensitive drills up to ½	¼– ¾

Radial Drills

Size	Horse-power	
	Average	Heavy
3-foot arm	1–2	3
4-foot arm	2–3	5 – 7½
5–6–7- foot arm	3–5	5 – 7½
8–9–10- foot arm	5–7½	7½–10

Gear Cutters

Size, Inches	Horse-power
36 x 9	2 – 3
48 x 10	3 – 5
30–60 x 12	5 – 7½
72 x 14	7½–10
64 x 20	10 –15

Cold Saws

Diam. Saw, Inches	Horse-power
20	3
26	5
32	7½
36	10–15
42	20
48	25
Hacksaws	½

Bolt Cutters

Single, Inches	Horse-power
1, 1¼, 1½	1–2
1¾, 2	2–3
2½, 3½	3–5
4, 6	5–7½
1, 1½ double	2–3
2, 2½ double	3–5
1, 1½, 2 triple	3–7½

Bolt Pointers

	Horse-power
1½, 2½ inches	1–2

Nut Tappers

	Horse-power
1, 2-inch 4-spindle	3
2-inch 6-spindle	3–5
2-inch 10-spindle	5
2-inch nut facer	3

Pipe Threading and Cutting-off Machines

Size of Pipe, Inches	Horse-power
¼– 2	2
½– 3	3
1¼– 6	3–5
2 – 8	3–5
3 –10	5
4 –12	5
8 –18	7½
24	10

Hammers

Size, Pounds	Horse-power
15– 75	½–5
100–200	5 –7½

Drop hammers require approximately 1 horse-power for every 100-pound weight of hammer head.

	Horse-power
100-pound Bradley hammer	3
200-pound Bradley hammer	5
350-pound Beaudry hammer	5

Bulldozers, Forming or Bending Machines

Width, Inches	Head Movement, Inches	Horse-power
29	14	5
34	16	7½
39	16	10
45	18	15
63	20	20

Bolt Headers (hot)

Size, Inches	Horse-power
¾–1½	5– 7½
1½–2	10–15

Upsetting Machines

Inches	Horse-power
2	7½–10
3	10 –15
5	15 –20
6	30 –40

Hyd. Wheel Press

Size, Tons	Horse-power
100	5
200–300	7½
400	10
600	15

Bending and Straightening Rolls

Width, Inches	Thickness, Inches	Horse-power
4–6	5/16– 3/8	5
6	7/16– 3/4	5–15
8	7/8	25
10	1⅛–1½	35–50
24	1	50

Shears

Gap Width, Inches	Horse-power Cut ½ Iron	Cut ¼ Iron
30–42	3	5
56–60	4	7½
72–96	5	10

Bolt shears	7½
Double-angle shears	10
Rotary bevel shears	7½

Plate Shears

Metal, Inches	Cut per Min.	Stroke, Inches	Horse-power
$\frac{3}{4}$ x 24	35	3	10
1 x 24	20	3	15
2 x 14	15	$4\frac{1}{4}$	30
1 x 42	20	4	20
$1\frac{1}{2}$ x 42	15	$4\frac{1}{2}$	60
$1\frac{1}{4}$ x 54	18	6	75
$1\frac{1}{2}$ x 72	20	$5\frac{1}{2}$	65
$1\frac{1}{4}$ x 100	10–12	$7\frac{1}{2}$	75

Lever Shears

Metal Cut, Inches	Horse-power
1 x 1	5
$1\frac{1}{2}$ x $1\frac{1}{2}$	$7\frac{1}{2}$
2 x 2	10
6 x 1	10
$2\frac{1}{2}$ x $2\frac{1}{2}$	10
1 x 7	15
$2\frac{3}{4}$ x $2\frac{3}{4}$	15
$1\frac{1}{2}$ x 8	20
$3\frac{1}{2}$ x $3\frac{1}{2}$	20
$4\frac{1}{2}$ round	30

Motors Usually Employed for Cranes and Hoists

Hoist		
Capacity, Tons	Speed, Feet per Minute	Horse-power
5	25	15
	50	25
10	30	25
	40	40
15	20	25
20	15	25
25	10	25
	15	33
30	14	33
5 aux.	50	25
10 aux.	25	25
50	10	40
5 aux.	50	25
10 aux.	25	25

Bridge			
Capacity, Tons	Span, Feet	Horse-power	Trolley Horse-power
5	60	20	3
10	80	25	3
15	80	25	5
20	80	25	5
25	80	25	5
30	80	33	$7\frac{1}{2}$
35	80	40	$7\frac{1}{2}$–10

POWER REQUIRED FOR PLANING-MILL EQUIPMENT

Band Saws

Diam. Wheel, Inches	Max. Width of Saw	Horse-power
30	$\frac{1}{2}$	2
34	$\frac{1}{2}$	3
36–38	$\frac{1}{2}$–$1\frac{1}{2}$	3–5
40–42	$\frac{1}{2}$–$1\frac{1}{2}$	3–$7\frac{1}{2}$

Cut-off Saws

Diam. Saw	No. of Saws	Horse-power
12–14	1	3
16	1	5
16	2	$7\frac{1}{2}$–10
30	1	$7\frac{1}{2}$

Circular Rip Saws

Diam. Saw	No. of Saws	Horse-power
14	1	5
16	1	$7\frac{1}{2}$
24	1	10
36	1	15

Surfacers

Size, Inches	No. Heads	Horse power	
30 x 6	1–2	15–20	Heavy Work
24 x 6	1–2	15–20	
30 x 8	2	30	
26 x 8	2	30	
24 x 6	1	5– $7\frac{1}{2}$	Light Work
16 x 6	1	5– $7\frac{1}{2}$	
24 x 8	1	10	
30 x 8	1	10	

Planers, Matchers and Flooring Machines

Size, Inches	Heads	Horse-power
9 x 8	4–5	30
19 x 8	4–5	30
24 x 8	4–5	40

Outside Moulders

Capacity, Inches	No. Heads	Horse-power
4 x 4	1–2	5
4 x 4	3–4	7½
6 x 4	1–2	5
6 x 4	3–4	7½
8 x 4	4	10
10 x 4	4	15
12 x 5	4	20

Inside Moulders

Inches		Horse-power
8 x 4	4	15
10 x 4	4	15
10 x 6	4–5	20–30

Jointers

Inches	Horse-power
8–12	2
16–24	3
30–36	5

Tenoning Machines

Inches	No. Heads	Horse-power
5½ x 14	1	3 –5
5½ x 15	2	5
23 x 9	2	7½
54 x 4½	4–8	10 –15
78 x 4½	4–8	10 –15
Gainers		7½–10 –15

Belt Sanders

Width of Belt, Inches	Horse-power
6–14	2–3
18	5

Drum Sanders

Length of Drum, Inches	Horse-power
30	7½
36	10
42–48	15
54–60	20
72– 84	30

Group Driving of Machines

There are many shops where group driving will be found more desirable than the use of individual motors, in both first cost and maintenance, particularly where the machines are comparatively small and run intermittently, as the cost of motors will be much less.

Friction load of 2½- to 3-inch shafting, with bearings 8 to 10 feet and running at 150 to 200 revolutions per minute, is about 1 horse-power for every 30 feet of shafting. This includes the friction of countershafts of the machines driven by it.

In group driving it is usually safe to select a motor having a rated capacity of from 25 to 30 per cent of the total power required for the machines in the group if this exceeds the maximum power needed by a single machine of the group.

Power Required for Punching and Shearing

Experiments tend to show that with steel plates of 60,000 pounds tensile strength, the metal is all sheared when the punch has passed one-third through the plate. The following formula by L. R. Pomeroy takes this into account and also allows the motor an efficiency of 80 per cent and the punching machine 75 per cent.

When T = full thickness of plate.
D = diameter of hole punched.
N = number of holes punched per minute.
P = horse-power required to drive machine.

$$P = \frac{T^2 \times D \times N}{3.78}.$$

Taking a $\frac{1}{2}$-inch hole in a $\frac{1}{2}$-inch plate, the power required to punch 30 per minute would be

$$\frac{\frac{1}{4} \times \frac{1}{2} \times 30}{3.78} = \frac{3.75}{3.78} \text{ or about 1 horse-power.}$$

Pressure required for shearing = length of cut × thickness in inches × shearing strength of material. Dies with "shear" reduce this one-third to one-half.

Power Required to Remove Metal

The power required to remove metal depends on the amount of metal removed per minute and the nature of the cutting tool. With a cutting angle of 75 to 80 degrees, tests show that for mild steel of 40-point carbon 1 horse-power will remove 1.5 cubic inches of metal per minute.

For average conditions and with tools as ordinarily used, tests show that to remove 1 cubic inch of metal per minute requires the amount of power shown in the table.

	Horse-power
Brass and similar alloys	0.2 –0.3
Cast iron	0.3 –0.5
Wrought iron	0.6
Mild steel (0.30 to 0.40 per cent carbon)	
Hard steel (0.50 per cent carbon)	1.00–1.25
Very hard tire steel	1.50

Two important factors enter into the problem of power for driving machines. These are the Time Factor and the Load Factor.

$$\text{Time Factor} = \frac{\text{Actual Cutting Time}}{\text{Total Time to Complete Operation}}.$$

$$\text{Load Factor} = \frac{\text{Average Daily Load}}{\text{Full-Load Rating of Motor}}.$$

Many tests give the following load factors:

The average load factor for motors driving lathes is from 10 to 25 per cent. On some special machines, as driving wheel and car-wheel lathes, the cuts are all heavy, increasing the average load factor to from 30 to 40 per cent.

For extension boring mills, 5-horse-power motors are used to move the housings on from 10- to 16-feet mills, $7\frac{1}{2}$ horse-power for from 14- to 20-feet mills and 10 horse-power for from 16- to 24-feet mills. The load factor of the driving motor on boring mills averages from 10 to 25 per cent.

The load factor of motor-driven drills is about 40 per cent when the larger drills applicable thereto are used. If the smaller drills are used the load factor averages 25 per cent and lower.

For the average milling operations the load factor averages from 10 to 25 per cent. On slab milling machines, where large quantities of metal are removed, it will average from 30 to 40 per cent.

The work on this class of machinery is usually light and much time is required in making adjustments. Hence the load factor is rarely higher than 20 per cent.

On planers the load factor averages between 15 and 20 per cent. With 10 horse-power or under belt-shifting drives probably give better results than direct-connected reversing motors.

The work done on shapers is of a varying character. With light work the load factor will not exceed from 15 to 20 per cent; with heavy work, the load factor will be as high as 40 per cent.

The conditions with slotters are similar to those on shapers.

Horse-power to Drive Machines

Extensive experiments by L. R. Pomeroy showed that the horse-power required equals the Feed per rev. or stroke × Depth of cut in inches × Cutting speed in feet per minute × 12 × Number of tools cutting × a Constant which depends on the material. This checks up fairly well with actual motor tests. The constants given are:

Cast iron	0.35 to 0.5
Wrought iron or soft steel	0.45 to 0.7
Locomotive driving wheel tires	0.70 to 1.00
Very hard steel	1.00 to 1.10

Handling this in another way, Charles Robbins of the Westinghouse Electric & Manufacturing Co. gives: The horse-power = Cubic inches removed per minute × a Constant. These constants are:

Brass and similar alloys	0.2 to 0.3
Cast iron	0.3 to 0.5
Wrought iron	0.6
Mild steel (0.30 to 0.40 carbon)	0.6
Hard steel (0.50 carbon)	1.00 to 1.25
Very hard tire steel	1.50

These represent average conditions with the cutting tools ordinarily used.

A brief summary of the studies by Mr. Robbins gives interesting data on various machines. These give factors as follows:

	Time Factor	Load Factor
Vertical boring machine	44%	27%
Radial drilling machine	41	10
Portable milling machine	54	55
Portable slotting machine	50	12
Planers	55	

L. R. Pomeroy also gave a method of determining the horse-power required by the belt used to drive the machine. The formula is:

Hp. = Thickness of belt in inches × Width of belt in inches × Diameter of pulley in inches × Revolutions per minute × Constant for kind of belt.

These constants are:

Leather belt	0.0062 to 0.0098
Cotton belt	0.0036 to 0.0068
Rubber belt	0.0050 to 0.0082

SPEED FOR WOOD TURNING

A good average speed for a wood turning lathe is a surface or cutting speed of from 1,000 to 1,500 ft. per minute. Where work does not exceed 1-in. diameter the lathe may be run 3,000 r.p.m.; for 2-in. stock 2,500; for 3-in., 2,000, or a little less, and for larger stock, the speed is reduced in proportion.

COOLING HOT BEARINGS

A hot box can be cooled by pouring sulphur on the bearing. It melts at 220 degrees and puts a smooth surface on both journals and bearings. It fills oil groove but can be dissolved with benzine if machine cannot be stopped. Either stick or flowers of sulphur will do. Graphite is also good but cannot be used where the color is objectionable as in flour mills or other white stock.

GUIDE TO THE SELECTION OF MOTORS

Type of Motor	Remarks
Shunt-wound motors	When the work is of a fairly steady nature. When a considerable range of speed adjustment is desired. When fairly close speed regulation is required.
Compound-wound motors	When there are sudden calls of short duration for heavy loads. When heavy starting duty is required. Where for these duties series motors could not be used on account of excessive light load speeds.
Series motors	When excessive starting torques are required, but only when speed regulation is not important and only when light load speeds do not exceed point of safety.
Squirrel-cage motors	When constant speed is desired and when normal starting duty is suitable.
Squirrel-cage motors, high-resistance rotors	Where heavy starting duty is needed or where high slip is necessary to prevent excess motor overloads or intermittent peak-load demands.
Slip-ring motors	When heavy starting duty is required and speed control is necessary. Maximum speed reduction practicable is 50 per cent. This is obtained by series resistor and speed is dependent on load.
Multi-speed motors	When direct current is not available. When three or four definite speeds, in conjunction with gear changes, will give desired speeds. For machine-tool service two-phase multi-speed motors are not recommended.
Control	When starting service is infrequent, and not severe, the dial type of controllers is suitable. Maximum of one start per hour is considered infrequent. In all other cases, drum or magnetic control is recommended.

Hints as to Proper Motor Selection for Various Machines

The following table is suggested by the General Electric Company as an aid in selecting the proper motor winding. For convenience, the table is divided into two parts. In general, machine tools used to remove metal by cutting tools or abrasives require shunt motors, and those used to shape metal require compound direct-current motors.

Motors for Machine Tools

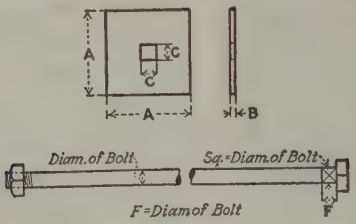
Tool	Direct Current		Alternating Current				Remarks
	Shunt	Comp.	Squirrel-Cage Rotor	Squirrel-Cage High-resistance Rotor	Multi-speed Squirrel Cage	Slip-ring Induction Motor	
Bolt cutter	×		×				From this table it will be seen that, with the exception of planers (reversing motor), motors may be either direct-current shunt-wound or alternating-current squirrel-cage type. Where the machine is of the constant-speed type, either alternating-current or direct-current motor may be used, depending upon the current supply. Where adjustable speed is required, the machine must be equipped with necessary gear changes, if alternating-current motor is employed. Multi-speed motors can be used with less complicated speed boxes.
Boring machines	×		×		×		
Boring mills	×		×		×		
Boring bars	×		×		×		
Centering machines	×		×				
Chucking machines	×		×				
Boring, milling and drilling machines	×		×		×		
Drill, radial	×		×		×		
Drill press	×		×		×		
Grinders	×		×				
Gear cutters	×		×		×		
Key seaters	×		×				
Lathes	×		×		×		
Milling machines	×		×				
Pipe cutters	×		×				

Planers—rotary	×		×				
Planers—reversing motor	×						
Saw—small circular	×		×				
Screw machine	×		×				
Shapers	×		×				
Slotters	×		×				
Tappers	×		×				
Bulldozers		×		×	×	×	
Bending rolls		×					×
Hammers—drop		×		×			×
Hammers—helve	*	×	*	×			
Lathe carriages—cross-rail		×		×			
Heading, upsetting and forging machines		×		×			×
Punch press	*	×	*	×			×
Planers—belt reversing		×	×				
Saw—friction		×	×	×			
Shears	*	×	×	×			
Shears—Rotary type	×		×				
Swaging	*	×	*	×			
Tumbling barrels or mills		×	×				

When speed adjustment is desired, use direct-current adjustable-speed motor, except where multi-speed alternating-current motor is wanted, and then only in conformity with paragraph on "multi-speed motors."

Squirrel-cage motors of the high-resistance rotor type approach the characteristics of direct-current compound-wound motors in that they provide the necessary slip, *i.e.*, slow down under load. This type of motor in capacities over 25 horse-power is not generally recommended because of the heat produced in the rotor. A wound rotor motor with external resistor to produce the desired slip is preferable.

*Where a machine is equipped with a flywheel for the purpose of producing energy during the work stroke, the motor slip should be sufficient to allow the flywheel to give up the maximum energy between cycles, and slow down just enough to require about full load on the motor at the end of the work stroke. In small machines of this type and where the actual work strokes are 35 per minute or more, a relatively low slip is needed, and standard motors can be used (shunt direct-current—squirrel-cage alternating-current). This is because there is not sufficient time, in a fast operating machine, to restore energy to the flywheel between work strokes. Obviously, a very light flywheel should be used.



FOUNDATION BOLTS AND WASHERS

DATA SHEET OF FOUNDATION BOLTS AND WASHERS USED AT THE CHESTER, PA., PLANT OF THE AMERICAN STEEL FOUNDRIES

Diam. of Bolt in Inches	*A* in Inches	*B* in Inches	*C* in Inches	Weight of Washer, Pounds	Weight of Bolt 1 Foot Long Including Head	Weight of Square Nut in Pounds	Weight of Square Head in Pounds	Weight of Each Additional Inch of Bolt, Pounds
½	5	⅜	⅝	2.61	0.76	0.085	0.094	0.056
⅝	5	⅜	¼	2.59	1.21	0.153	0.168	0.087
¾	6	⅜	⅜	3.74	1.77	0.250	0.273	0.125
¾	6	⅜	1	3.71	2.46	0.381	0.416	0.170
1	6	⅜	1½	3.69	3.27	0.552	0.598	0.223
1⅛	6	⅜	1½	3.65	4.21	0.769	0.834	0.282
1¼	6	⅜	1⅝	3.62	5.29	1.03	1.12	0.348
1⅜	6	⅜	1¾	3.58	6.51	1.35	1.46	0.421
1½	8	½	1⅝	8.68	7.87	1.72	1.87	0.501
1⅝	8	½	1¾	8.62	9.40	2.17	2.35	0.588
1¾	8	½	1⅞	8.56	11.09	2.69	2.91	0.682
1⅞	8	½	2	8.49	12.93	3.26	3.54	0.782
2	12	½	2¼	29.61	14.95	3.94	4.27	0.890
2¼	12	½	2½	29.37	19.72	5.51	6.00	1.127
2½	12	½	2¾	29.10	24.84	7.49	8.15	1.391

The table gives the necessary data from which the weights of bolts from ½ to 2½ inches in diameter can be computed. The weights of the nuts and the sizes and weights of the washers are also given.

STEEL AND OTHER METALS

HEAT TREATMENT OF STEEL

The theory of the heat treatment of steel rests upon the influence which the rate of cooling has on certain molecular changes in structure occurring at different temperatures in the solid state. These changes are of two classes, critical and progressive; the former occur periodically between certain narrow temperature limits, while the latter proceed gradually with the rise in temperature, each change producing alterations in the physical characteristics. By controlling the rate of cooling, these changes can be given a permanent set, and the physical characteristics can thus be made different from those in the metal in its normal state.

The highest temperature to which it is safe to submit a steel for heat treating is governed by the chemical composition of the steel. Very low carbon steel may be heated to about 1650 degrees Fahr. but high carbon tool steels will harden at a lower temperature. The steel maker's advice as to the best hardening temperature should be given careful consideration. From 1400 to 1450 deg. Fahr. is usually sufficient. Some of the high-grade alloy steels may safely be raised to 1750 degrees Fahr., and the high-speed steels may be raised to just below the melting point, usually from 2000 to 2150 degrees Fahr. It is necessary to raise the metal to these points so that the active cooling process will have the desired effect of checking the crystallization of the structure.

Methods of Heating

Furnaces using solid fuel, such as coal, coke, charcoal, etc., are the most numerous and have been used the longest. These furnaces consist of a grate to place the fuel on, an arch to reflect the heat and a plate to put the pieces on. The plate should be so arranged that the flames will not strike the pieces to be heated, and for that reason some use cast-iron or clay retorts which are open on the side toward the doors of the furnace.

The use of both gas and oil furnaces is increasing, owing to the ease with which the fire is handled and the cleanliness as compared with a coal, coke or charcoal fire. The electric furnace is also growing in use, the ease with which heat can be controlled being an important factor.

Heating in Liquids

Furnaces using liquid for heating have a receptacle, such as a pot or crucible, to hold the liquid, which is heated by coal, oil, gas or other means; the liquid is kept at the highest temperature to which the piece should be heated. The piece should be preheated slowly in an ordinary furnace to about 800 degrees, after which it

should be immersed in the liquid bath and kept there long enough to attain the temperature of the bath and then removed to be annealed or hardened.

The bath usually consists of lead, although antimony, cyanate of potassium, chloride of barium, a mixture of chloride of barium and chloride of potassium in the proportion of 3:2, mercury, common salt and metallic salts have been successfully used.

This method gives good results, as no portion of the piece to be treated can reach a temperature above that of the liquid bath; a pyrometer attachment will indicate exactly when the piece has arrived at that temperature. The bath can be maintained easily at the proper temperature and the entire process is under perfect control.

When lead is used it is liable to stick to the steel unless it is pure and retard the cooling of the spots where it adheres. Impurities, such as sulphur, are liable to be absorbed by the steel and thus affect its chemical composition. With high temperatures, lead and cyanate of potassium throw off poisonous vapors which make them prohibitive, and even at comparatively low temperatures these vapors are detrimental to the health of the workmen in the hardening room unless great care is used in exhausting the fumes by mechanical means. The metallic, salts, however, do not give off these poisonous vapors, and are much better to use for this purpose, but many times the fumes are unbearable.

Gas and Oil as Fuel

Furnaces using gaseous fuel are very numerous and are so constructed that they can use either natural gas, artificial gas or producer gas. They are very easy to regulate and if well built are capable of maintaining a constant temperature within a wide range.

In first cost this style of furnace is greater than that of the solid fuel furnaces, but where natural or producer gas is used the cost of operating is so much less that the saving soon pays for the cost of installation. Illuminating gas, however, is more expensive than the solid fuels and is only used where high-grade work demands the best results from heat treatment.

Oil-fired furnaces are also being used in large numbers.

U. S. ARMORY BROWNING SOLUTION

First, make "tincture of steel," by putting 3 pounds of carbonate of iron in a stone jar and pouring over this 3 quarts of muriatic acid. Let this stand, stirring it occasionally, until the acid "cuts" or takes up all of the iron that it will. After the muriatic acid becomes saturated with the carbonate of iron, pour it into a glass demijohn, being careful that none of the remaining sediment goes with it. To this add 9 quarts of grain alcohol, completing the tincture of steel.

To make the Browning solution proper, take 6 ounces of the tincture of steel, 6 ounces sweet spirits of niter, 1 ounce nitric acid, ½ ounce sulphate of copper, 1 ounce corrosive sublimate, and 2

quarts of soft water, using a glass stopped bottle to prevent evaporation.

This should stand for 24 hours if possible, although it can be used immediately but does not give as good results. The solution is applied with a sponge.

U. S. ARMORY ETCHING ACID

There are sometimes pieces that are riveted in place after being browned. As the riveting must be smoothed down, thereby removing the browning, a special etching acid is used for coloring the polished portions to match the browning previously put on. The etching acid is comprised of 1 ounce tincture of steel, previously mentioned, 2 ounces corrosive sublimate and 1 ounce nitric acid. Some of the etching acid is put in a shallow glass dish and the parts to be colored are dipped into it. In order to check the working of this acid, the parts are immediately dipped in hot water and then in a dish of ammonia at full strength, and finally covered with oil.

HOW TO NITER-BLUE STEEL

Immerse the chemically clean components in a mixture of 10 parts of niter (salt peter) to 1 part of black oxide of manganese (MnO_2), by weight, heated to 800 to 850 degrees Fahr. The mixture should be contained in a cast-iron pot, heated by any suitable fuel.

Best results are obtained when the components are contained in a wire basket. They are allowed to remain in the niter for from 5 to 10 minutes, the longer the time the darker the blue.

Upon withdrawing the components, quench them in water at a temperature of from 125 to 150 degrees Fahr. and when dry cover them with raw linseed oil and allow them to drain.

Springs are generally drawn back at from 450 to 600 degrees Fahr., depending upon the analysis of the steel. Higher carbon content requires higher temperature. Even the 600 degree tempering temperature is too low for the niter-bluing process and another method must be used. To get good results have the springs clean and then heat them on the surface of a layer of sand, contained in a pan, either in the furnace or by a fire applied underneath the pan, until the color desired has been obtained. The parts should be turned occasionally during the heating, and after the coloring has been completed they should be spread out to cool.

QUENCHING OR COOLING STEEL

Cooling apparatus is divided into two classes—baths for hardening and the different appliances for annealing.

The baths for quenching are composed of a large variety of materials. Some of the more commonly used are as follows, being arranged according to their intensity on 0.85 per cent carbon steel: Mercury; water with sulphuric acid added; nitrate of potassium; sal ammoniac; common salt; carbonate of lime; carbonate of magnesia; pure water; water containing soap, sugar, dextrine or alcohol; sweet milk; various oils; beef suet; tallow; wax. These baths, however,

do not act under all conditions with the same relative intensity, as their conductivity and viscosity vary greatly with the temperature.

With the exception of the oils and some of the greases, the quenching effect increases as the temperature of the bath lowers. Sperm and linseed oils, however, at all temperatures between 32 and 250 degrees Fahr., act about the same as distilled water at 160 degrees.

ARSENAL "HOT DIP" PROCESS FOR TINNING

Use a metal composed of 80 parts of lead to 20 parts of tin by weight. The steel plate to be tinned is first pickled in a bath of 40 parts of water to one part of sulphuric acid by volume. After pickling, the metal is washed in clean water to remove all traces of the pickling acid. The work is then dipped in a flux which is made by dissolving zinc in hydrochloric acid until it is saturated. After dipping in the flux, the pieces are dipped in the melted metal (80% lead — 20% tin) until thoroughly coated and are then shaken off and thrown in a pile to cool.

A Method of Tinning Brass Parts

Brass parts are placed in layers in a screened basket with tin plates between each layer. They are then placed in a copper tank filled with water supplied with steam coil and brought to a boiling point. Sufficient amount of Cream of Tartar is added until the parts are properly plated. Four hours are required to properly tin these parts.

Small parts are placed in a cheese cloth bag in a solution of one pint of phosphoric acid (U.S.P. 50%) to four gallons of water. Heat to a boiling point until parts begin to turn white, requiring about two hours. Remove and place in linseed oil. They are then rolled on straw boards to remove the surplus oil.

The Hardening Bath

In hardening steels the influence of the bath depends upon its temperature, its mass and its nature; or, to express this in another way, upon its specific heat, its conductivity, its volatility and its viscosity. With other things equal, the lower the temperature of the bath, the quicker will the metal cool and the more pronounced will be the hardening effect. Thus water at 60 degrees will make steel harder than water at 150 degrees, and when the bath is in constant use the first piece quenched will be harder than the tenth or twentieth, owing to the rise in temperature of the bath. Therefore if uniform results are to be obtained in using a water bath, it must either be of a very large volume or kept cool by some mechanical means. In other words, the bath must be maintained at a constant temperature.

The mass of the bath can be made large, so no great rise in temperature is made by the continuous cooling of pieces, or it can be made small and its rise in temperature used for hardening tools that are to remain fairly soft, as, if this temperature is properly regulated, the tool will not have to be reheated and tempered later, and cracks and fissures are not as liable to occur.

Another way of arriving at the same results would be to use the double bath for quenching, that is, to have one bath of some product similar to salt which fuses at 575 degrees Fahr. Quench the piece in that until it has reached its temperature, after which it can be quenched in a cold bath or cooled in the air.

BATH FOR DRAWING TEMPER

A VERY good table from which to make up baths for drawing the temper is as follows:

Composition of Bath Lead and Tin	Melting Point in Degrees F.	Color of Steel at Temperature Given	Good Temper for Carbon Steel
14 8	420	Very faint yellow	
15 8	430	Faint yellow	
16 8	440	Light straw	
17 8	450	Straw	Drills, taps, dies, reamers, punches and shear blades
18.5 8	460	Full straw	
20 8	470	Dark straw	
24 8	480	Old gold	
28 8	490	Brown	Cold chisels, large punches, beading and calking tools
38 8	510	Brown with purple spots	
60 8	530	Purple	
96 8	550	Deep purple	Smith's tools, swages, hot and cold cutters
200 8	560	Blue	
Boiling linseed oil	600	Dark blue	Boiler snaps or sets, stamping and pressing dies
Melted lead	610	Gray blue	

These are used in a similar manner to the hardening baths, selecting the bath which gives the proper drawing temperature.

Annealing

The appliances for annealing are as numerous as the baths for quenching, and where a few years ago the ashes from the forge were all that were considered necessary for properly annealing a piece of steel, today many special preparations are being manufactured and sold for this purpose.

The more common materials used for annealing are powdered charcoal, charred bone, charred leather, slacked lime, sawdust, sand, fire clay, magnesia or refractory earth. The piece to be annealed is usually packed in a metal box, using some of these materials or combinations of them for the packing; the whole is then heated in a furnace to the proper temperature and set aside, with the cover left on, to cool gradually to the atmospheric temperature.

While cast-iron boxes are most common, there is an increasing use of such alloys as nicrome (nickel and chromium) on account of their longer life under continual heating and cooling.

For certain grades of steel these materials give good results; but for all kinds of steels and for all grades of annealing the slow-cooling furnace perhaps gives the best satisfaction, as the temperature can be easily raised to the right point, kept there as long as necessary, and then regulated to cool down as slowly as is desired. The gas, oil or electric furnaces are the easiest to handle and regulate. For annealing tool steel, about 1400 degrees Fahr. is usually sufficient.

Annealing is now used to designate heating for the purpose of softening. To remove stresses in steel it is heated above the calescent point. This is called "normalizing."

HIGH-SPEED STEELS

These steels are made by alloying tungsten and chromium or molybdenum and chromium with steel. These compositions completely revolutionize the points of transformation. Chromium, which has a tendency to raise the critical temperature, when added to a tungsten steel, in the proportions of 1 or 2 per cent, reduces the critical temperature to below that of the atmosphere. Tungsten and molybdenum prolong the critical range of temperatures of the steel on slow cooling so that it begins at about 1300 degrees Fahr. and spreads out all the way down to 600 degrees.

These steels are heated to 1850 degrees for the molybdenum and 2200 degrees for the tungsten, and are cooled moderately fast, usually in an air blast, to give them the property known as "red-hardness." This treatment prevents the critical changes altogether and preserves the steel in what is known as the austenitic condition. The austenitic condition is one of hardness and toughness.

One rule which has given good results in heat treating these high-speed steels is to heat slowly to 1500 degrees Fahr., then heat fast to 2200 degrees; after which cool rapidly in an air blast to 1550 degrees; then cool either rapidly or slowly to the temperature of the air. Others advocate cooling in crude oil.

ALLOY STEEL DEVELOPMENT

Alloy steels have been developed to meet the needs of modern industry which required tougher, stronger and harder steels than can be obtained in simple carbon steels. The growth of the automobile has been made possible by this development, which, in turn, came to meet the needs of the automobile builders. The alloy steels vary widely in kind of alloy and in the proportion of alloy and of carbon content. The special alloy should be chosen to suit the particular requirements of each special case, although there are, of course, several alloy steels which will satisfactorily cover a large variety of requirements. It must be remembered, however, that no alloy steel is a universal steel and best for all purposes.

The making of alloy steel requires care as much of its value depends upon its being uniform both in physical and in machining qualities.

Chrome Nickel Steel

Chrome nickel steel is made with both high and low carbon content. It possesses excellent static qualities but is not generally recommended on account of being more difficult to forge, to machine and to heat-treat than the other alloy steels. Makers claim that it has no physical characteristic which cannot be secured more cheaply by either nickel steel or chrome vanadium steel. Not only does chrome nickel cost more but the machining and other shop processes also cost more than with the other alloy steels.

Chrome Vanadium Steel

Chrome vanadium steel ranks very high in the estimation of both makers and users, and is made with both high and low carbon content as are the chrome nickel steels. The high carbon alloy is recommended for springs and constant mesh gears which are to be oil-hardened.

The low-carbon chrome vanadium steels are used for work which is to be case-hardened or is to be oil-tempered and annealed for such uses as clash gears in automobiles, for axles, steering knuckles and similar parts where strength without a trace of brittleness must be obtained. By different blendings of these alloys it is believed to be possible to secure practically every static property which can be obtained from nickel, chrome-nickel, silico-manganese or other alloys. With proper heat treatment this alloy also has splendid dynamic or anti-fatigue qualities which make it extremely desirable for automobile and similar work.

Chrome vanadium steel also forges and machines easily, being considered superior in these respects to chrome nickel steels with corresponding carbon percentages.

Molybdenum

Molybdenum steels have been made for 25 years, but were not widely used until a few years ago. One part of molybdenum is equal to 2 or $2\frac{1}{2}$ parts of tungsten in tool steels and in magnet steels. If has not been in favor for high-speed tool steels, however, because the molybdenum is driven out of the surface of the tool during the forging and heat treatment.

For use in automobiles and other high-grade machinery, 1 per cent of molybdenum greatly enhances certain properties of heat-treated carbon and alloy steels.

Recommended Specifications for Molybdenum Steels
(Percentages)

S.A.E. Steel No.	Carbon Range	Manganese Range	Phosphorus, Maximum	Sulphur, Maximum	Chromium Range	Nickel Range	Molybdenum Range
4130	0.25–0.35	0.40–0.70	0.04	0.045	0.50–0.80	.....	0.15–0.25
4140	0.35–0.45	0.40–0.70	0.04	0.045	0.80–1.10	.....	0.15–0.25
4150	0.45–0.55	0.40–0.70	0.04	0.045	0.80–1.10	.....	0.15–0.25
4615	0.10–0.20	0.30–0.50	0.04	0.045	.....	1.25–1.75	0.20–0.30

The various ingredients of steel may be summed up as follows in the working of steel:

Ingredient	Its Effect
Iron	The basis of all steel.
Carbon	The determinative.
Sulphur	The strength sapper.
Phosphorus	The weak link.
Oxygen	A strength destroyer.
Manganese	Adds strength.
Nickel	Adds strength and toughness.
Tungsten	Hardener and heat resister.
Chromium	For resisting shocks.
Vanadium	Purifier and fatigue resister.
Silicon	Impurity and hardener.
Titanium	Removes nitrogen and oxygen.
Molybdenum	Hardener and heat resister.
Aluminum	Kills or deoxidizes steel.

Nickel Steel

Nickel steel, when made with care and uniformity, is perhaps the most generally useful of the alloy steels. With reasonable care nickel steel can be made uniform, physically sound and free cutting in the machine shop. It can be heat-treated in numerous ways to secure different characteristic qualities and has a wide field of usefulness. It machines well and can be case-hardened very satisfactorily.

Stainless Steel

To the Firth Company of Sheffield, England, is given credit for "stainless" or 12 to 14 per cent high-chromium steel. The name is patented, but all high-chromium steels are frequently called by similar names. Owing to its great strength at high temperatures, it is used for such purposes as valves for internal-combustion engines, blades for turbines, etc. Great care must be taken in forging to avoid "cold shorts," as stresses due to unequal cooling are called.

To anneal for machining, it should be heated to 2400 or 2500 degrees Fahr., held at this point for about an hour and then allowed to cool in air. It can also be cooled in oil without appreciable hardening. When so annealed it machines about the same as 3 per cent nickel or nickel-chromium steel. To harden this steel it is heated to about 2900 degree Fahr. and quenched in either oil or water.

Functions of Different Elements.—We can sum up the different elements in ordinary alloy steels to have the following functions: Carbon for hardness and rigidity; manganese for toughness; silicon a sort of adjuster; sulphur and phosphorus as lubricants; chromium as a refiner of grain and to add hardness to help carbon; nickel as a protecting support of structure and as an aid to stability, and vanadium in small doses acts as a scavenger, in high percentage it is a great resister of friction.

In heat-treating alloy steel there are certain factors to bear in mind. These factors may vary slightly as to the duration of heat limits, but they are always present, and the following points must be considered:

First: We must know the critical points.

Second: We must not fall below high critical point when soaking steel.

Third: Steel of the same analysis must have the same length of time for soaking to give uniform results.

Fourth: Quenching must be done within certain limits of temperature, depending on the quality of the work performed, or uniform results cannot be obtained.

Fifth: Tempering heats vary on a 10-degree Fahr. basis; very close heat limits must be established for the quality of work desired.

Sixth: A low limit must be set as to the time necessary for soaking at high heat. This heat must not fall below the heat wanted while being soaked, for if it does, the timing must begin when this temperature is again reached. Too long soaking may cause a reaction, giving a dry steel with a great drop in elastic strength.

Seventh: When taken out of the furnace the work should be buried in lime and thoroughly covered with no chance for air pockets. Air-cooled steel will contain hard spots on the surface and soft spots in the interior. If no information is at hand as to the critical points of steel they can very easily be ascertained by pyrometer or magnet methods.

The Calescent and Recalescent Points.—The calescent point can be determined by use of the pyrometer by closely watching its needle. The thermocouple, or fire end should be inserted in the steel. Drill a hole in the piece to take in the fire end of thermocouple. As the heat advances the needle will follow until it reaches a point where it suddenly stops, wavers and then suddenly drops several degrees, although the heat is constantly advancing; then the needle will again suddenly commence its upward swing. Where the needle stops its upward swing and rests is the calescence, or low critical, point.

Now reverse the operation. Heat beyond the critical point and shut off the fuel and watch for the same phenomena. The needle will fall with heat, suddenly stop, then advance several degrees, when it again starts to drop for good. This upper change is called the recalescence point.

You can also test with an ordinary horseshoe magnet. Touch the steel with magnet during heating and the temperature at which the steel fails to attract the magnet, or in other words loses its magnetism, is the point of calescence, or critical, point.

Even Heating Necessary.—Strains in steel are very often caused by having no heat circulation about the work, particularly when heating in furnace, by work being placed on the furnace floor. Circulation of heat is necessary, and the best method is to lay long pieces or strips on raised perforated platforms.

The furnace should be "balanced;" in other words, the heat must be evenly distributed; in fact several firing ends should be in the furnace at all times, connected by switch to the same pyrometer. The cooling agent should also be kept within very close temperature limits.

Colors of Heated Steel in Diffused Daylight

The following list of colors is given by the Vanadium Corporation of America:

Colors	Degrees Fahr.
Dark blood red or black red	990
Dark red, blood red or low red	1050
Dark cherry red	1175
Medium cherry red	1250
Cherry, full red	1375
Light cherry, bright cherry, *scaling heat	1550
Salmon, orange, free scaling heat	1650
Light salmon, light orange	1725
Yellow	1825
Light yellow	1975
White	2200

* Scaling heat: Scales just form but do not fall away when cooling.

TEMPERING COLORS FOR VARIOUS TOOLS

Kind of tool	Temperature, Degrees Fahr.	Color	Action of file	Other indications
Scrapers for ordinary use Burnishers	200	.....	.....	Water dries quickly.
Light turning and finishing tools Engraving tools	430	Very pale yellow	Can hardly be made to catch	Lard oil smokes slightly
Lathe tools Milling cutters Lathe and planer tools for heavy work Taps Dies for screw cutting Reamers Punches Dies Flat drills	460	Straw-yellow	Can be made to catch with difficulty	
Woodworking tools Plane irons Wood chisels Wood turning tools Twist drills Sledges Blacksmiths' hammers	500	Brown-yellow		
Cold chisels for very light work	530	Light purple	Scratches	
Axes	550	Dark purple		
Cold chisels for ordinary use	.....	Blue, tinged slightly with red.		
Stone-cutting chisels	.....	.....	Files with great difficulty	
Carving knives Screwdrivers Saws				
Springs	580 610 630	Blue Pale blue Greenish blue	Files with difficulty	Lard oil burns or flashes

HEAT TREATMENT OF SPRING STEEL

The following heat treatment for springs has been recommended by the American Society of Steel Treaters. The steels referred to are C, carbon; Cr, chromium; CrV, chrome-vanadium; CrMo, chrome-molybdenum; CrSiMn, chrome-silicon-manganese; SiMn, silicon-manganese.

The steel is normalized when considerable machining is required, when severe cold working is to be done or when the product has been subjected to localized heating at several places for the purpose of forging. The normalizing temperatures are given below:

HEAT TREATMENTS FOR LEAF AND COIL SPRINGS

Steel	Normalizing Temperature, Degrees Fahr.	Hardening Temperature, Degrees Fahr.	Approximate Tempering Temperature,† Degrees Fahr.	Brinell Hardness Number
C	1575–1625	1525	600–950	352–415
Cr	1600–1650	1525	650–950	363–444
CrV	1600–1675	1550–1600	675–975	363–444
CrMo	1600–1675	1550–1600	675–975	363–444
CrSiMn	1600–1650	1600–1650	675–975	363–444
SiMn	1600–1650	1600–1650	650–950	363–444

† The tempering temperatures are to be used only as a guide in obtaining the Brinell hardness numbers given in the table.

CASE-HARDENING

CASE-HARDENING, carbonizing or carburizing is largely used so that the outer shell can be made hard enough to resist wear, while the core of the piece can be left soft enough to withstand the shock strains to which it is subjected.

Case-hardening is, in reality, the quenching of the metal after its surface has absorbed carbon so that it hardens on being quenched suddenly. Generally speaking, carbon is absorbed from bone, leather or similar materials, while the low-carbon steel is properly packed and heated. Another method allows the carbon to be absorbed from gas instead of from solid materials.

The result of the carbonizing operation is determined by five factors, which are as follows: first the nature of the steel; second, the nature of the carbonizing material; third, the temperature of the carbonizing furnace; fourth, the time the piece is submitted to the carbonizing process; fifth, the heat treatment which follows carbonizing.

If the steel used has a carbon content up to 56 points, the rate of penetration in carburizing is practically constant; but the higher the carbon content is, in the core, the more brittle it becomes by prolonged annealing after carburizing. Therefore it is necessary that the carbon content should be low in the core, and for this reason a preference is given to steels containing from 15 to 20 points of carbon for carburizing or case-hardening purposes and the carbon brought up to 80 or 85 points. Tool steels may be carbonized up to 250 points, a point is one-tenth of 1 per cent.

Manganese, chromium, tungsten and molybdenum increase the rate of penetration. Nickel, silicon, titanium and aluminum retard the rate of penetration—5 per cent of silicon reducing it to zero

The Carbonizing Materials

The nature of the carbonizing materials has an influence on the speed of penetration and it is very essential that the materials be of a known chemical composition, as this is the only way to obtain like results on the same steel at all times.

These materials or cements are manufactured in many special and patented preparations. The following materials are used and compounded in these preparations, but many of them give as good results when used alone as when compounded with others in varying percentages: powdered bone; wood charcoal; charred sugar; charred leather; cyanide of potassium; ferrocyanide of potassium; bichromate of potassium; animal black, acid cleaned; prussiate of potash; anthracite; mixture of barium carbonate; graphite; petroleum gas; acetylene; horn, etc.

Wood charcoal is very largely used in carburizing steels, but the value of this material varies with the wood used, the method employed in making the charcoal and other factors. Used alone it gives the normal rate of penetration for the first hour, but after that the rate gradually decreases until at 8 hours it gives the lowest rate of penetration of any of the carburizing materials. The best wood charcoal is that made from hickory.

Powdered charcoal and bone give good results as a carburizing material and are successfully used in carburizing nickel-chrome steel by packing in a pot and keeping at a temperature of about 2000 degrees Fahr. for four hours, and then cooling slowly before taking out the pot or uncovering it. Pots are made of cast iron, nichrome or other heat-resisting alloys.

The General Motors Company specify that carburizing material be made from charcoal, coke and carbonate energizers. Hardwood charcoal must be used, and it must pass through a $\frac{3}{8}$-inch sieve, but not through a $\frac{1}{8}$-inch mesh. Coke of Solvay process or equivalent and of same size as charcoal.

Two compositions are used:

	G. M. C. 2002 M	G. M. C. 2001-M
Coke	Not over 25 per cent	Not over 25 per cent
Sodium carbonate	3–5 per cent	8–12 per cent
Calcium carbonate	3–5 per cent	
Barium carbonate	5–7 per cent	
Total sulphur	Not over 0.5 per cent	Not over 0.25 per cent
Moisture	Not over 4. per cent	Not over 6 per cent
Charcoal and binder	Balance	Balance

Inorganic matter, exclusive of carbonates—Not over 8 per cent.

Not less than 97 per cent of mixture must pass through a 0.371-inch opening and not over 5 per cent through a 0.131-inch screen.

The shrinkage by volume shall not be over 25 per cent on a 6-hou run at 1700 degree Fahr.

TABLE I

Temperature in Degrees Fahrenheit for Eight Hours	Materials Used and Rate of Penetration in Inches			
	Charcoal 60 Per Cent + 40 Per Cent of Carbonate of Barium	Ferrocyanide 66 Per Cent + 34 Per Cent of Bichromate	Ferrocyanide Alone	Powdered Wood Charcoal Alone
1300				
1475	0.020	0.033	0.020	0.020
1650	0.088	0.069	0.079	0.048
1825	0.128	0.128	0.128	0.098
2000	0.177	0.177	0.198	0.138

COLORS IN CASE-HARDENING

Wrenches and other work of low-carbon steel may be case hardened and at the same time given an attractive coloring o "mottling" by exercising a little care in the process. The work must be perfectly clean and free from grease, and should be nicely polished. Unless this is done, bright colors cannot be secured.

To secure good colors, the bone must be thoroughly charred. This can be done by covering it tightly in iron boxes and placing in the furnace at night or when the heat is going down. If too ho it will burn instead of charring.

The work should be even more carefully packed than for case hardening without color, leaving more space between the work itself and between the work and the box. The degree of heat and the length of time must, of course, depend on the size of the work but, generally speaking, a cherry red is correct. The main thing however, is to maintain an even heat. If the heat is too great, it is impossible to receive a good color, or any color.

The work must be dumped without exposing them to the air. It is customary to suspend a sieve beneath the surface of the water in the tank to catch the pieces as they are dumped. The water should be soft for best results, and should be kept in motion. There should be sufficient volume, or the water should change often enough to cool the work quickly. A stream of air blowing through the water also helps to agitate it and to secure good coloring. Small lots, of course, do not require as large an amount of water.

The dumping of the work must be carefully done. The box should be held close to water and dumped quickly. Should the air strike the work before it is quenched, it is almost sure to turn black or blue-black and be streaky.

After cooling, the work is taken out, separated from the bone and boiled in clean water. It is then dried in sawdust and oiled slightly which brings out the colors and prevents tarnish.

Further coloring may be done by tumbling the work in a barrel until the work is thoroughly polished. It is then placed over a gas flame or other source of heat and drawn to the desired color, much as we draw the temper on hardened steel. The articles are then plunged in cold water, dried in sawdust and oiled. Combustion of the fire used must be good, as any gas given off affects the color.

Use of Bone and Charcoal.—Case-hardening with granulated raw bone is a common practice in many large manufacturing plants. Bone which is hard and flinty, such as that which comes from the shin bones of animals, is considered better than soft, pithy and greasy bone, as there is no waste. Good bone can be used over and over again by adding fresh stock to it in about the proportion of 1:2 or 3. In other words, use two or three parts of old bone to one part of new, raw bone.

Raw bone is usually white and burns black when first used. As it loses its carbon it becomes lighter and when it burns white it is of no further value for case-hardening. Some raw bone, on the other hand, is quite dark, and only experience with the various materials will make a person familiar with the best mixtures to use for different purposes.

Some case-hardeners secure good results and economize on the use of bone by mixing one part of raw bone with three parts of pulverized charcoal. The mixing should be thorough and a little charcoal dust sprinkled over the top.

Where the tendency of case-hardened work to scale is objectionable, a thin layer of charred leather next to the work will help to check the scaling.

Case Hardening Large Flat Work.—The larger the piece the more bone should be used in packing it for case-hardening. With a disk approximately 4 inches thick and 24 inches in diameter, the lower layer of bone should be from 4 to 5 inches thick, and the same distance allowed all around the disk. The side to be hardened should be placed down and the top covered to about the same depth as the bottom, and the cover luted in place.

A piece of this size will probably require 8 or 10 hours' soaking at a bright cherry red; it should not be heated above this temperature on account of the increased tendency to warp. This tendency can also be overcome by dipping edgewise into a large body of cold, running water so as to remove the heat quickly. Salt water is also advised in dipping heavy work, as it conducts the heat away more rapidly than fresh water.

Sometimes a mixture of half charcoal and half used bone is used with low-carbon steel. This will not recarbonize much more than 5 per cent, or about enough to maintain the original amount of carbon in the steel.

Small or thin iron castings can be annealed by packing in a cast-iron pot or box with a mixture of bright cast-iron turnings or filings and pulverized charcoal. Use about half charcoal and half turnings or filings. Put a layer of the mixture between the castings to prevent warping and to allow them to heat more evenly.

Heat to a cherry red and hold this heat for from 2 to 3 hours. The castings must be left in the pots to cool off.

Sizes of Granulated Bone.—The Rogers & Hubbard Co. give the following list of sizes of granulated raw bone:

No. 1. Will not pass through smaller than $\frac{1}{4}$-inch square mesh in screen. Best for heavy work.

No. 2. Mesh $\frac{1}{8}$-inch square.

No. 3. Mesh $\frac{1}{8}$-inch square.

Nos. 2 and 3 are best for bicycle, fire arms, sewing machine and general machine work.

No. 4. Mesh $\frac{1}{12}$ inch square. Good for small work, such as small screws, etc.

No. 5. Smaller than $\frac{1}{12}$ inch. Used only for the very finest work.

CASE-HARDENING CAST IRON

A bath recommended for hardening cast iron for various reasons, such as gaging or locating points, is made up of 16 ounces of sulphuric acid, 1 ounce of nitric acid and 1½ gallons of water. The piece is heated to a bright red and quenched in the mixture.

Selecting the Proper Temperature for Quenching

A hardening process that will produce a steel that is as homogeneous as possible is always sought for in practice. This is easily obtained in a high-carbon steel, and especially if it contains 85 points carbon, by passing the recalescent point before quenching. The desired homogeneity is not so easily obtained, however, in the low-carbon steels, as they have several points of transformation. If these are quenched at a point a little above the lowest point of transformation the carbon will pass into solution, but the solution is not homogeneous. To obtain this result it is necessary that the quenching be done from a little above the highest point of transformation. This is higher in the low- than in the high-carbon steels. In practice, this calls for a quenching of the low-carbon steels as about 1650 degrees Fahr., while a high-carbon steel should be quenched at about 1450 degrees.

Testing Pyrometers

Pyrometers can be tested by placing some common salt in an iron box and heating until it melts. Put the pyrometer in the molten salt and, if correct, it will register 1441 degrees Fahr.

A very convenient table of Fahrenheit and Centigrade thermometer scales is given on pages 703 and 704.

AUTOMOTIVE STEELS

The engineers of the automobile industry have developed a number of steels and heat treatments that are equally useful in many other lines of work. These steels are designated by numbers with "S. A. E." before them, meaning the steels have been approved and recommended by the Society of Automotive Engineers. The most commonly used steels are given herewith. The uses and heat treatments follow. The letters G. M. C. (General Motors Company) as applied to steel are practically the same as S. A. E.

Table of Automobile Steels

GENERAL MOTORS COMPANY

Number	Per Cent Carbon	Per Cent Manganese	Per Cent Phosphorus (Maximum)	Per Cent Sulphur (Maximum)	Per Cent Nickel	Per Cent Chromium
G. M. C. 1010	0.05–0.15	0.30–0.50	0.05	0.055		
G. M. C. 1020	0.15–0.25	0.30–0.50	0.05	0.055		
G. M. C. 1025	0.20–0.30	0.30–0.50	0.05	0.055		
G. M. C. 1035	0.30–0.40	0.50–0.80	0.05	0.055		
G. M. C. 1045	0.40–0.50	0.50–0.80	0.05	0.055		
G. M. C. 1095	0.90–1.05	0.25–0.50	0.045	0.05		
G. M. C. 1112	0.08–0.16	0.60–0.80	0.09–0.13	0.075–0.15		
G. M. C. 1120	0.15–0.25	0.60–0.80	0.05	0.075–0.12		
G. M. C. 2115	0.10–0.20	0.30–0.50	0.035	0.04	0.40–0.60	
G. M. C. 2315	0.10–0.20	0.30–0.50	0.045	0.05	3.25–3.75	
G. M. C. 2520	0.15–0.25	0.40–0.60	0.045	0.05	4.75–5.25	
G. M. C. 3115	0.10–0.20	0.30–0.50	0.045	0.05	1.00–1.50	0.45–0.75
G. M. C. 3135	0.30–0.40	0.50–0.70	0.045	0.05	1.00–1.50	0.45–0.75
G. M. C. 3145	0.40–0.50	0.50–0.70	0.045	0.05	1.00–1.50	0.45–0.75
G. M. C. 3250	0.45–0.55	0.30–0.50	0.025	0.025	1.50–2.00	0.90–1.20
G. M. C. 4155	0.50–0.60	0.85–1.15	0.045	0.05		
G. M. C. 5150	0.45–0.55	0.60–0.80	0.04	0.04		0.85–1.10

CHARACTERISTICS, USES AND HEAT TREATMENTS

G. M. C. 1010.—Yield point annealed 25,000 to 32,500 pounds; cold rolled or drawn, 40,000 to 60,000 pounds per square inch. This is a very soft open-hearth steel and in the annealed condition will stand much deformation without cracking. In the natural condition it has very low strength. Its yield point is raised considerably by cold working. It machines very poorly in the soft condition. The properties are but little affected by heat treatment.

Uses.—This steel is most suitable for seamless tubing, rivets, and pressed steel parts which will be subjected to the most difficult of cold-forming operations. It is also used for some carburized parts where extreme ductility of core is highly essential.

Caution.—Annealing of cold-worked parts will materially lower the yield point. Annealing of cold-drawn work between operations must be carefully done to avoid coarsening the grain in the higher carbons.

Typical Heat Treatment.—When used for carburizing:
Carburize 1650 to 1700 degrees Fahr.
Cool in pots or quench in oil or water.
Reheat to 1675 to 1700 degrees Fahr.
Quench in oil.
Reheat to 1400 to 1425 degrees Fahr.
Quench in water.
Where a hard surface only is desired and the ductility of the core is unimportant, the first reheat to 1700 degrees can be omitted.

No. 1020.—Yield point annealed 30,000 to 40,000 pounds; cold rolled or drawn, 40,000 to 75,000 pounds; heat treated, 40,000 to 75,000 pounds per square inch. This steel forges well but does not machine well in the natural or annealed state. The machineability can be improved by cold working or by quenching from above 1520 degrees Fahr.

Uses.—This steel is recommended for carburized parts, such as piston pins, cam shafts, rocker arms, valve lifters, shifter rods, rollers, etc. It can be used for unimportant forgings where little strength is necessary and on which little machining is required.

Typical Heat Treatment.—
Carburize 1650 to 1700 degrees Fahr.
Cool in pots or quench in oil or water.
Reheat to 1550 to 1575 degrees Fahr.
Quench in oil.
Reheat to 1400 to 1425 degrees Fahr.
Quench in water.
Where a hard surface only is desired and the ductility of the core is unimportant, the reheat to 1575 degrees can be omitted.

No. 1025.—Yield point 35,000 to 45,000 pounds; cold rolled or drawn, 45,000 to 75,000 pounds; heat treated, 40,000 to 75,000 pounds per square inch. This steel is a fairly free machining grade, especially if cold worked. It usually is not carburized because of the resultant brittle core.

Uses.—Especially recommended in the hot or cold rolled sheet form for pressed parts, such as frames, rear-axle housings, etc. It

an also be used for forgings which are not highly stressed and on which there is not too much machining.

Caution.—Forgings to be carburized should be made of 1015 or 1020 steel. Forgings made from No. 1025 steel may be heat treated, but should not be carburized. The gain in strength from heat treatment is slight, although the toughness can be materially increased. Forgings for structural parts should be made from the higher-carbon or alloy steels.

Typical Heat Treatment.—Heat to 1575 to 1600 degrees Fahr.
Quench in water.
Draw as required.

No. 1035.—Yield point 40,000 to 50,000 pounds; cold rolled, 50,000 to 80,000 pounds; heat treated, 45,000 to 85,000 pounds per square inch. This steel forges well and machines freely after cold working or a quenching treatment with a good draw. It can be treated to show a combination of fairly high strength with a great deal of toughness. If there is little machining to be done, unimportant forgings may be made from this stock with no treatment. Forgings which have heavy duty to perform must be given heat treatment.

Uses.—This steel is suitable for structural purposes. It should be used for ordinary forged parts generally, except where a high degree of strength is required. It is especially recommended for parts which have moderate to heavy duty to perform, where there is considerable shock or where alternating stresses are encountered, as in front I-beams, steering knuckles, third arms, connecting rods, unhardened shifting forks, etc. This steel should never be carburized.

Typical Heat Treatment.—Heat to 1550 to 1575 degrees Fahr.
Quench in oil or water.
Draw as required.

No. 1045.—Yield point 45,000 to 50,000 pounds; cold rolled or drawn, 50,000 to 90,000 pounds; heat treated, 50,000 to 120,000 pounds per square inch. This steel is a structural steel of greater strength than No. 1035. When treated properly it shows considerable toughness in combination with a high degree of strength, while at the same time its fatigue-resisting (endurance) qualities are higher than that of the lower carbon steels. After annealing, cold working or quenching with a good draw, this steel machines freely. All parts made from this steel, with the exception of cold-drawn shafting, are meant to be heat treated.

Uses.—The uses of this steel are more limited than No. 1035 and are confined to such parts as require a high degree of strength with considerable toughness. Especially recommended for parts generally of medium to large sections, which have severe duty, or which do not receive excessive shock, as in crank shafts, propeller shafts and rear-axle shafts.

Typical Heat Treatment.—Heat to 1500 to 1550 degrees Fahr.
Quench in water or oil.
Draw as required.

No. 1095.—This material is used as a spring steel. It readily assumes a high hardness, being very high-carbon steel.

Uses.—Generally used for springs, especially recommended for medium to large automobile leaf springs.

Typical Heat Treatment.—Heat to 1400 to 1500 degrees Fahr.
Quench in oil.
Draw as required.

No. 1112.—In the cold-drawn condition this steel machines freely and is liable to be brittle.

Uses.—This steel is suitable for low-stressed screw machine parts, as in ordinary studs, bolts, etc., because of its rapid machining properties. Never use this material where there is any severe duty involved.

Caution.—Parts made from this steel should not receive any heat treatment except in very special cases. Screw machine parts to be carburized should be made of steel No. 1120, cold drawn, or in some instances No. 1020 may be used.

No. 1120.—This steel will be made by open-hearth process and will be known as open-hearth screw stock. Its composition and texture are of such a nature as to permit the rapid removal of metal and smoothness of finish. The steel will be somewhat tougher and more difficult to machine than No. 1112.

Uses.—It is to be used for carburized parts where good machineability is desirable and where extreme ductility of core is not essential.

Typical Heat Treatment.—Similar to steel No. 1020.

No. 2115.—Yield point annealed, 30,000 to 37,500 pounds; heat treated, 37,500 to 65,000 pounds per square inch. This steel, after carburizing, can be treated in oil so as to have a hard wearing surface with a tough core.

Uses.—This steel is especially recommended for ring gears.

Typical Heat Treatment.—Carburize 1650 to 1675 degrees Fahr.
Cool in pots.
Reheat to 1600 to 1650 degrees Fahr.
Quench in oil.
Reheat to 1350 to 1400 degrees Fahr.
Quench in oil.

No. 2315.—Yield point, anncaled, 35,000 to 45,000 pounds; heat treated, 40,000 to 80,000 pounds per square inch. This steel is recommended for carburizing purposes, and when properly treated will produce a part with an exceedingly tough and strong core, coupled with the desired hard surface. The case-hardening sequence may be varied considerably, those parts of relatively small importance requiring a simpler form of treatment. As a rule, however, those parts which require the use of nickel steel require the most scientific type of heat treating.

Uses.—This steel is especially recommended for Rear Drive Pinion Gears. For practically all other carburized alloy parts, 3115, which is considerably cheaper, can be used.

Caution.—Parts of intricate shape with sudden changes of thickness, sharp corners and the like, particularly sliding gears, should always be drawn after hardening, in order to relieve the internal strains.

Typical Heat Treatment.—Carburize 1625 to 1675 degrees Fahr.
Cool in pots or quench in oil.
Reheat to 1550 to 1575 degrees Fahr.
Quench in oil.

Reheat to 1300 to 1350 degrees Fahr.
Quench in oil or water.

No. 2520.—Yield point, annealed, 40,000 to 50,000 pounds; heat treated, 60,000 to 100,000 pounds per square inch. This steel is used for carburized parts where the service required is extremely severe and where it is necessary to have a core of the utmost ductility. The parts should be very carefully heat treated to take advantage of the possibilities in this steel. This steel should not be specified except where No. 2315 has proved unsatisfactory.

Uses.—This steel is being used for pinion gears, steering worm sectors, etc., where extremely high duty is required.

Typical Heat Treatment.—Carburize at 1625 to 1675 degrees Fahr.
Cool in pots or quench in oil.
Reheat to 1550 to 1575 degrees Fahr.
Quench in oil.
Reheat to 1300 to 1350 degrees Fahr.
Quench in oil.
Draw to 350 degrees Fahr.

No. 3115.—Yield point, annealed, 35,000 to 50,000 pounds; heat treated; 40,000 to 80,000 pounds per square inch. This steel is recommended for carburizing purposes and when properly heat treated will produce a part with a core having a high yield point and considerable ductility coupled with a very hard surface. It is cheaper than steel No. 2315.

Uses.—This steel is especially recommended for use on all carburized parts requiring an alloy steel, except rear-axle pinions.

Caution.—Parts of intricate shape with sudden changes of thickness, sharp corners and the like, particularly sliding gears, should always be drawn after hardening, in order to relieve the internal strains.

Typical Heat Treatment.—Carburize at 1625 to 1675 degrees Fahr.
Cool in pots or quench in oil.
Reheat to 1550 to 1575 degrees Fahr.
Quench in oil.
Reheat to 1375 to 1400 degrees Fahr.
Quench in water or oil.

No. 3135.—Yield point, annealed, 45,000 to 60,000 pounds; heat treated, 55,000 to 150,000 pounds per square inch. This steel is especially recommended where great strength and freedom from brittleness are desired. Oil or water quench followed by suitable drawing at desired temperatures gives the required properties.

Uses.—Especially suitable for parts which have severe duty to perform, in which there is not too great shock encountered, such as in propeller shafts, rear-axle shafts, transmission countershafts, etc. Also suited for the more important bolts, such as connecting-rod bolts, crank-case bolts, studs and keys.

Typical Heat Treatment.—Heat to 1475 to 1500 degrees Fahr.
Quench in oil or water.
Draw as required.

No. 3145.—Yield point, annealed, 50,000 to 65,000 pounds; heat treated, 115,000 to 240,000 pounds per square inch. This steel is recommended for parts that require a very high elastic limit

in combination with good ductility. It is considerably stronger than steel No. 3135.

Uses.—Especially suitable for gears and very high-duty transmission shafts.

Typical Heat Treatment.—Heat to 1440 to 1460 degrees Fahr.
Cool slowly.
Brinell between 4.20- and 4.80-millimeter diameter.
Machine.
Heat to 1440 to 1460 degrees Fahr.
Quench in oil.
Draw as required.

No. 3250.—Yield point, annealed, 55,000 to 70,000 pounds; heat treated, 150,000 to 265,000 pounds per square inch. This steel is difficult to forge. It must be soaked thoroughly at not too high a temperature. If forged at too low a temperature it is liable to crack. In any heating operations, the heat must be applied slowly, or cracks are liable to develop. This steel does not machine readily unless great care is taken in annealing. This steel is a higher-grade steel than G. M. C. No. 3145 and is considerably more expensive.

Uses.—Useful for purposes where unusual strength is required. Especially suited for transmission gears and high-duty shafting.

Typical Heat Treatment.—Heat to 1475 to 1500 degrees Fahr. and hold 2 hours.
After steel is heated, then cool slowly.
Heat to 1425 to 1450 degrees Fahr.
Quench in oil.
Draw as required.

No. 4155.—Yield point, annealed, 50,000 to 60,000 pounds; cold-rolled or drawn, 55,000 to 95,000 pounds; heat treated, 125,000 to 175,000 pounds per square inch. This steel has great fatigue-resisting properties which make it useful for springs.

Uses.—This steel is almost universally used for coil springs, such as valve springs, clutch springs, brake springs, motor support springs, etc.

Typical Heat Treatment.—Heat to 1450 degrees Fahrenheit.
Quench in oil.
Draw 700 to 900 degrees Fahrenheit.

No. 5150.—Yield point, annealed, 60,000 to 80,000 pounds; heat treated, 150,000 to 275,000 pounds per square inch. This is an electric furnace steel having, after proper heat treatment, a very high elastic limit in combination with fair ductility. It can be treated to show great hardness and wearing qualities.

Uses.—Especially suited for transmission gears and other parts where hardness and high elastic limit are required.

Typical Heat Treatment.—Heat to 1575 to 1600 degrees Fahrenheit.
Hold 2 hours after steel is soaked through at this temperature.
Cool slowly with furnace.
Brinell between 4.00- and 4.40-millimeter diameter.
Machine.
Heat to 1450 to 1475 degrees Fahrenheit.
Quench in oil.
Draw as required.

TEMPERATURE CONVERSION TABLES

−459.4–0				1–50				51–100				101–750			
C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.
−273	**−459.4**	−134	**−210**	−346	−17.2	**1**	33.8	−3.33	**26**	78.8	10.6	**51**	123.8	24.4	**76**	168.8	43	**110**	230	177	**350**	662	260	**500**	932
−268	**−450**	−129	**−200**	−328	−16.7	**2**	35.6	−2.78	**27**	80.6	11.1	**52**	125.6	25.0	**77**	170.6	49	**120**	248	182	**360**	680	266	**510**	950
−262	**−440**	−123	**−190**	−310	−16.1	**3**	37.4	−2.22	**28**	82.4	11.7	**53**	127.4	25.6	**78**	172.4	54	**130**	266	188	**370**	698	271	**520**	968
−257	**−430**	−118	**−180**	−292	−15.6	**4**	39.2	−1.67	**29**	84.2	12.2	**54**	129.2	26.1	**79**	174.2	60	**140**	284	193	**380**	716	277	**530**	986
−251	**−420**	−112	**−170**	−274	−15.0	**5**	41.0	−1.11	**30**	86.0	12.8	**55**	131.0	26.7	**80**	176.0	66	**150**	302	199	**390**	734	282	**540**	1004
−246	**−410**	−107	**−160**	−256	−14.4	**6**	42.8	−0.56	**31**	87.8	13.3	**56**	132.8	27.2	**81**	177.8	71	**160**	320	204	**400**	752	288	**550**	1022
−240	**−400**	−101	**−150**	−238	−13.9	**7**	44.6	0	**32**	89.6	13.9	**57**	134.6	27.8	**82**	179.6	77	**170**	338	210	**410**	770	293	**560**	1040
−234	**−390**	− 95.6	**−140**	−220	−13.3	**8**	46.4	0.56	**33**	91.4	14.4	**58**	136.4	28.3	**83**	181.4	82	**180**	356	216	**420**	788	299	**570**	1058
−229	**−380**	− 90.0	**−130**	−202	−12.8	**9**	48.2	1.11	**34**	93.2	15.0	**59**	138.2	28.9	**84**	183.2	88	**190**	374	221	**430**	806	304	**580**	1076
−223	**−370**	− 84.4	**−120**	−184	−12.2	**10**	50.0	1.67	**35**	95.0	15.6	**60**	140.0	29.4	**85**	185.0	93	**200**	392	227	**440**	824	310	**590**	1094
−218	**−360**	− 78.9	**−110**	−166	−11.7	**11**	51.8	2.22	**36**	96.8	16.1	**61**	141.8	30.0	**86**	186.8	99	**210**	410	232	**450**	842	316	**600**	1112
−212	**−350**	− 73.3	**−100**	−148	−11.1	**12**	53.6	2.78	**37**	98.6	16.7	**62**	143.6	30.6	**87**	188.6	100	**212**	413	238	**460**	860	321	**610**	1130
−207	**−340**	− 67.8	**− 90**	−130	−10.6	**13**	55.4	3.33	**38**	100.4	17.2	**63**	145.4	31.1	**88**	190.4	104	**220**	428	243	**470**	878	327	**620**	1148
−201	**−330**	− 62.2	**− 80**	−112	−10.0	**14**	57.2	3.89	**39**	102.2	17.8	**64**	147.2	31.7	**89**	192.2	110	**230**	446	249	**480**	896	332	**630**	1166
−196	**−320**	− 56.7	**− 70**	− 94	− 9.44	**15**	59.0	4.44	**40**	104.0	18.3	**65**	149.0	32.2	**90**	194.0	116	**240**	464	254	**490**	914	338	**640**	1184
−190	**−310**	− 51.1	**− 60**	− 76	− 8.89	**16**	61.8	5.00	**41**	105.8	18.9	**66**	150.8	32.8	**91**	195.8	121	**250**	482				343	**650**	1202
−184	**−300**	− 45.6	**− 50**	− 58	− 8.33	**17**	63.6	5.56	**42**	107.6	19.4	**67**	152.6	33.3	**92**	197.6	127	**260**	500				349	**660**	1220
−179	**−290**	− 40.0	**− 40**	− 40	− 7.78	**18**	65.4	6.11	**43**	109.4	20.0	**68**	154.4	33.9	**93**	199.4	132	**270**	518				354	**670**	1238
−173	**−280**	− 34.4	**− 30**	− 22	− 7.22	**19**	67.2	6.67	**44**	111.2	20.6	**69**	156.2	34.4	**94**	201.2	138	**280**	536				360	**680**	1256
−169	**−273**	−459.4 − 28.9	**− 20**	− 4	− 6.67	**20**	68.0	7.22	**45**	113.0	21.1	**70**	158.0	35.0	**95**	203.0	143	**290**	554				366	**690**	1274
−168	**−270**	−454 − 23.3	**− 10**	14	− 6.11	**21**	69.8	7.78	**46**	114.8	21.7	**71**	159.8	35.6	**96**	204.8	149	**300**	572				371	**700**	1292
−162	**−260**	−436 − 17.8	**0**	32	− 5.56	**22**	71.6	8.33	**47**	116.6	22.2	**72**	161.6	36.1	**97**	206.6	154	**310**	590				377	**710**	1310
−157	**−250**	−418			− 5.00	**23**	73.4	8 89	**48**	118.4	22.8	**73**	163.4	36.7	**98**	208.4	160	**320**	608				382	**720**	1328
−151	**−240**	−400			− 4.44	**24**	75.2	9.44	**49**	120.2	23.3	**74**	165.2	37.2	**99**	210.2	166	**330**	626				388	**730**	1346
−146	**−230**	−382			− 3.89	**25**	77.0	10.0	**50**	122.0	23.9	**75**	167.0	37.8	**100**	212.0	171	**340**	644				393	**740**	1364
−140	**−220**	−364																					399	**750**	1382

NOTE.—The numbers in bold-face type refer to the temperature either in degrees Centigrade or Fahrenheit which it is desired to convert into the other scale. If converting from Fahrenheit degrees to Centigrade degrees the equivalent temperature will be found in the left column, while if converting from degrees Centigrade to degrees Fahrenheit, the answer will be found in the column on the right. These tables are a revision of those by Albert Sauveur, Professor of Metallurgy and Metallography, Harvard University, Cambridge, Mass. Copyright, 1920.

INTERPOLATION FACTORS

C.		F.	C.		F.
0.56	**1**	1.8	3.33	**6**	10.8
1.11	**2**	3.6	3.89	**7**	12.6
1.67	**3**	5.4	4.44	**8**	14.4
2.22	**4**	7.2	5.00	**9**	16.2
2.78	**5**	9.0	5.56	**10**	18.0

TEMPERATURE CONVERSION TABLES—*Continued*

751–1250			751–1250			1251–1750			1751–2250			2251–3000			2251–3000		
C.		F.	C.		F.	C.		F.	C.		F.	C.		F.	C.		F.
404	**760**	1400	543	**1010**	1850	682	**1260**	2300	816	**1500**	2732	960	**1760**	3200	1099	**2010**	3650
410	**770**	1418	549	**1020**	1868	688	**1270**	2318	821	**1510**	2750	966	**1770**	3218	1104	**2020**	3668
416	**780**	1436	554	**1030**	1886	693	**1280**	2336	827	**1520**	2768	971	**1780**	3236	1110	**2030**	3686
421	**790**	1454	560	**1040**	1904	699	**1290**	2354	832	**1530**	2786	977	**1790**	3254	1116	**2040**	3704
427	**800**	1472	566	**1050**	1922	704	**1300**	2372	838	**1540**	2804	982	**1800**	3272	1121	**2050**	3722
432	**810**	1490	571	**1060**	1940	710	**1310**	2390	843	**1550**	2822	988	**1810**	3290	1127	**2060**	3740
438	**820**	1508	577	**1070**	1958	716	**1320**	2408	849	**1560**	2840	993	**1820**	3308	1132	**2070**	3758
443	**830**	1526	582	**1080**	1976	721	**1330**	2426	854	**1570**	2858	999	**1830**	3326	1138	**2080**	3776
449	**840**	1544	588	**1090**	1994	727	**1340**	2444	860	**1580**	2876	1004	**1840**	3344	1143	**2090**	3794
454	**850**	1562	593	**1100**	2012	732	**1350**	2462	866	**1590**	2894	1010	**1850**	3362	1149	**2100**	3812
460	**860**	1580	599	**1110**	2030	738	**1360**	2480	871	**1600**	2912	1016	**1860**	3380	1154	**2110**	3830
466	**870**	1598	604	**1120**	2048	743	**1370**	2498	877	**1610**	2930	1021	**1870**	3398	1160	**2120**	3848
471	**880**	1616	610	**1130**	2066	749	**1380**	2516	882	**1620**	2948	1027	**1880**	3416	1166	**2130**	3866
477	**890**	1634	616	**1140**	2084	754	**1390**	2534	888	**1630**	2966	1032	**1890**	3434	1171	**2140**	3884
482	**900**	1652	621	**1150**	2102	760	**1400**	2552	893	**1640**	2984	1038	**1900**	3452	1177	**2150**	3902
488	**910**	1670	627	**1160**	2120	766	**1410**	2570	899	**1650**	3002	1043	**1910**	3470	1182	**2160**	3920
493	**920**	1688	632	**1170**	2138	771	**1420**	2588	904	**1660**	3020	1049	**1920**	3488	1188	**2170**	3938
499	**930**	1706	638	**1180**	2156	777	**1430**	2606	910	**1670**	3038	1054	**1930**	3506	1193	**2180**	3956
504	**940**	1724	643	**1190**	2174	782	**1440**	2624	916	**1680**	3056	1060	**1940**	3524	1199	**2190**	3974
510	**950**	1742	649	**1200**	2192	788	**1450**	2642	921	**1690**	3074	1066	**1950**	3542	1204	**2200**	3992
516	**960**	1760	654	**1210**	2210	793	**1460**	2660	927	**1700**	3092	1071	**1960**	3560	1210	**2210**	4010
521	**970**	1778	660	**1220**	2228	799	**1470**	2678	932	**1710**	3110	1077	**1970**	3578	1216	**2220**	4028
527	**980**	1796	666	**1230**	2246	804	**1480**	2696	938	**1720**	3128	1082	**1980**	3596	1221	**2230**	4046
532	**990**	1814	671	**1240**	2264	810	**1490**	2714	943	**1730**	3146	1088	**1990**	3614	1227	**2240**	4064
538	**1000**	1832	677	**1250**	2282				949	**1740**	3164	1093	**2000**	3632	1232	**2250**	4082
									954	**1750**	3182						

2251–3000			2251–3000		
C.		F.	C.		F.
1238	**2260**	4100	1371	**2500**	4532
1243	**2270**	4118	1377	**2510**	4550
1249	**2280**	4136	1382	**2520**	4568
1254	**2290**	4154	1388	**2530**	4586
1260	**2300**	4172	1393	**2540**	4604
1266	**2310**	4190	1399	**2550**	4622
1271	**2320**	4208	1404	**2560**	4640
1277	**2330**	4226	1410	**2570**	4658
1282	**2340**	4244	1416	**2580**	4676
1288	**2350**	4262	1421	**2590**	4694
1293	**2360**	4280	1427	**2600**	4712
1299	**2370**	4298	1432	**2610**	4730
1304	**2380**	4316	1438	**2620**	4748
1310	**2390**	4334	1443	**2630**	4766
1316	**2400**	4352	1449	**2640**	4784
1321	**2410**	4370	1454	**2650**	4802
1327	**2420**	4388	1460	**2660**	4820
1332	**2430**	4406	1466	**2670**	4838
1338	**2440**	4424	1471	**2680**	4856
1343	**2450**	4442	1477	**2690**	4874
1349	**2460**	4460	1482	**2700**	4892
1354	**2470**	4478	1488	**2710**	4910
1360	**2480**	4496	1493	**2720**	4928
1366	**2490**	4514	1499	**2730**	4946
			1504	**2740**	4964
			1510	**2750**	4982

NOTE.—The numbers in bold-face type refer to the temperature either in degrees Centigrade or Fahrenheit which it is desired to convert into the other scale. If converting from Fahrenheit degrees to Centigrade degrees the equivalent temperature will be found in the left column, while if converting from degrees Centigrade to degrees Fahrenheit, the answer will be found in the column on the right. These tables are a revision of those by Albert Sauveur, Professor of Metallurgy and Metallography, Harvard University, Cambridge, Mass. Copyright, 1920.

INTERPOLATION FACTORS

C.		F.	C.		F.
0.56	**1**	1.8	3.33	**6**	10.8
1.11	**2**	3.6	3.89	**7**	12.6
1.67	**3**	5.4	4.44	**8**	14.4
2.22	**4**	7.2	5.00	**9**	16.2
2.78	**5**	9.0	5.56	**10**	18.0

To convert Fahrenheit into Centigrade: Subtract 32 from Fahrenheit, divide remainder by 9 and multiply by 5.

Example: 212 Fahr.

$$\frac{32}{180} \quad 180 \div 9 = 20. \quad 20 \times 5 = 100.$$

Ans. 212 Fahr. = 100 Cent.

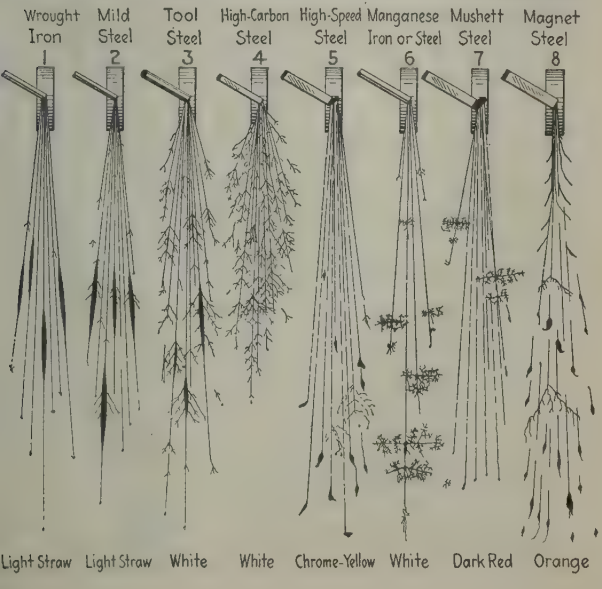
Centigrade to Fahrenheit: Divide by 5, multiply by 9 and add 32.

Example: 260 Cent. $\div$ 5 = 52. $52 \times 9 = 468 + 32 = 500$ Fahr.

Ans. 260 Cent. = 500 Fahr.

THE SPARK METHOD OF DETERMINING GRADES OF IRON AND STEEL

The method of determining the kind of ferrous material illustrated herewith was devised by John F. Keller, instructor of forging at Purdue University, Lafayette, Ind., and has proved very successful as a practical shop test. The illustrations and notes make further explanations unnecessary. The material should touch the wheel lightly and the spark be carefully watched.



TEST OF HARDNESS

The hardness of metals, particularly of steels which are heat treated, is now tested with either the Shore scleroscope, or by the Brinell or Rockwell method, as described on page 708.

THE BRINELL TEST

The Brinell method of testing consists of forcing a hardened steel ball of given dimension into the metal to be tested under a given pressure. The diameter of the impression made is read with a graduated microscope and the hardness found by consulting the table herewith. In this the ball is 10 millimeters in diameter. If, with a pressure of 3,000 kilograms, as indicated by the testing machine, the diameter of the depression is 3 millimeters, the hardness number is 418. Dividing this by 6 gives practically 70, as shown under the second column. According to this table, a pressure of only 500 kilograms will give a direct reading which is about the same as that of the scleroscope. The standard pressure, however, is 3,000 kilograms.

TABLE OF BRINELL HARDNESS NUMERALS—STEEL BALL OF 10 MILLIMETERS DIAMETER

Diameter of Impression, Millimeters	Hardness Numeral Pressure, Kilograms		Diameter of Impression, Millimeters	Hardness Numeral Pressure, Kilograms		Diameter of Impression, Millimeters	Hardness Numeral Pressure, Kilograms		Diameter of Impression, Millimeters	Hardness Numeral Pressure, Kilograms		Diameter of Impression, Millimeters	Hardness Numeral Pressure, Kilograms	
	3000	500		3000	500		3000	500		3000	500		3000	500
2.0	946	158	3.0	418	70	4.0	228	38.0	5.0	143	23.8	6.0	95.0	15.9
2.05	898	150	3.05	402	67	4.05	223	37.0	5.05	140	23.3	6.05	94.0	15.6
2.10	857	143	3.10	387	65	4.10	217	36.0	5.10	137	22.8	6.10	92.0	15.3
2.15	817	136	3.15	375	63	4.15	212	35.0	5.15	134	22.3	6.15	90.0	15.1
2.20	782	130	3.20	364	61	4.20	207	34.5	5.20	131	21.8	6.20	89.0	14.8
2.25	744	124	3.25	351	59	4.25	202	33.6	5.25	128	21.5	6.25	87.0	14.5
2.30	713	119	3.30	340	57	4.30	196	32.6	5.30	126	21.0	6.30	86.0	14.3
2.35	683	114	3.35	332	55	4.35	192	32.0	5.35	124	20.6	6.35	84.0	14.0
2.40	652	109	3.40	321	54	4.40	187	31.2	5.40	121	20.1	6.40	82.0	13.8
2.45	627	105	3.45	311	52	4.45	183	30.4	5.45	118	19.7	6.45	81.0	13.5
2.50	600	100	3.50	302	50	4.50	179	29.7	5.50	116	19.3	6.50	80.0	13.3
2.55	578	96	3.55	293	49	4.55	174	29.1	5.55	114	19.0	6.55	79.0	13.1
2.60	555	93	3.60	286	48	4.60	170	28.4	5.60	112	18.6	6.60	77.0	12.8
2.65	532	89	3.65	277	46	4.65	166	27.8	5.65	109	18.2	6.65	76.0	12.6
2.70	512	86	3.70	269	45	4.70	163	27.2	5.70	107	17.8	6.70	74.0	12.4
2.75	495	83	3.75	262	44	4.75	159	26.5	5.75	105	17.5	6.75	73.0	12.2
2.80	477	80	3.80	255	43	4.80	156	25.9	5.80	103	17.2	6.80	71.5	11.9
2.85	460	77	3.85	248	41	4.85	153	25.4	5.85	101	16.9	6.85	70.0	11.7
2.90	444	74	3.90	241	40	4.90	149	24.9	5.90	99	16.6	6.90	69.0	11.5
2.95	430	72	3.95	235	39	4.95	146	24.4	5.95	97	16.2	6.95	68.0	11.3

THE ROCKWELL TEST

The Rockwell test is a modification of the Brinell. It consists of pressing a hardened steel ball or a diamond cone of 120-degrees angle into the article to be tested and measuring the depth of impression with a dial micrometer The size of impression is much smaller than in the Brinell test, as the steel ball is only $\frac{1}{16}$ inch in diameter and the maximum major load is only 150 kilograms (330 pounds) when using the diamond cone and 100 kilograms (220 pounds) when using the steel ball. Arrangement is also made to apply a smaller load of 60 kilograms (132 pounds), if desired, for soft metals. The method of applying the Rockwell test is different from the Brinell in that the total depth of depression from the surface is not measured. In making the Rockwell test the minor load of 60 kilograms, (132 pounds), regulated by a spring, is first applied to the ball or cone; the micrometer dial is then set at zero, or at a fixed point, and then the major load is applied. Upon releasing the major load the depth of impression caused by the major load only is indicated on the micrometer dial. By using a special reading glass, the diameter of depression of a steel ball can be read the same as in the Brinell test. The Rockwell test does not require a standard specimen, it does not spoil the finish of the article tested, except on very high-polished work, and it can be used on much thinner sections than the Brinell (0.010 inch for iron and 0.015 inch for brass); it cannot, however, be used for testing thin sections that are brittle or cannot stand a permanent deformation.

SCLEROSCOPE READING

In the Shore Scleroscope, a miniature drop hammer tup falls from a fixed height to the surface of the metal being tested. The height of the rebound indicates the hardness on an arbitrary scale which has 115 divisions, these meeting all usual requirements. This method can be applied to any material which will take a permanent set under impact. For, no matter how hard the material, the falling weight, weighing about 40 grains, makes a dent which can be seen with a glass.

The following table shows the readings which will be obtained on the Scleroscope for the materials indicated, this giving the comparative hardness of the materials.

SCLEROSCOPE HARDNESS SCALE

Metal	Annealed	Hammered
Lead — cast	2– 5	3– 7
Babbitt	4– 9	
Gold	5	8½
Silver	6½	20– 30
Brass — cast	7–35	
Pure Tin — cast	8	12
Brass — drawn	10–15	20– 45
Bismuth — cast	9	
Platinum	10	17
Copper — cast	6	14– 20
Zinc — cast	8	20
Iron — pure	18	25– 30
Mild steel, 0.15 carbon	22	30– 45
Nickel Anode — cast	31	55
Iron, gray — cast	30–45	
Iron, gray — chilled		50– 90
Steel, tool, 1% carbon	30–35	40– 50
Steel, tool, 1.65% carbon	35–40	
Vanadium steel	35–45	
Chrome — Nickel	47	
Chrome — Nickel, hardened		60– 95
Steel, high speed, hardened		70–105
Steel, carbon, tool, hardened		90–110

NOTE.—These figures vary with the composition and density of the metals. They are about $\frac{1}{6}$ those of the Brinell test for equal hardness, varying somewhat with the kind of metal.

Hardness Strength of Steel

The following table (prepared by Sir Robert Hadfield of the Research Laboratory, Hadfields, Ltd., Sheffield, Eng.) represents the average of a large number of tests on all types of steel, and is intended as an approximate guide. Individual results vary considerably from the average. It also gives a comparison of Brinell ball and scleroscope hardness numbers with their relation to the compression strength, also yield point and tenacity of steel.

Zones of Hardness F to A	Approx. Scleroscope Hardness Number	Brinell Ball Hardness Number	Tensile Strength				Compression on Specimens .564" Diam. and .70" in Height		
			Yield Point		Maximum Stress		Elastic Limit and 25% Compression		
			Tons per Sq. In.	Kilograms per Sq. M/M	Tons per Sq. In.	Kilograms per Sq. M/M	Tons per Sq. In.	Kilograms per Sq. M/M	Compression, Per Cent. (100 Tons per Sq. In.) (100 Kilograms) per Sq. M/M
F		150	20	31	36	57	17	27	49.0
		175	26	41	41	65	19	30	40.0
	34	200	32	50	46	72	21	32	35.0
E	38	225	38	60	51	80	23	36	31.0
	42	250	44	69	56	88	26	41	27.9
	46	275	50	79	61	96	30	47	23.0
	50	300	56	88	66	104	34	54	19.0
D	54	325	61	96	71	112	38	60	15.2
	57	350	67	105	76	120	43	68	11.3
	61	375	73	115	81	128	49	77	8.0
	64	400	79	124	86	135	55	87	5.6
C	68	425	84	132	91	143	61	96	3.8
	71	450	90	142	96	151	67	105	2.4
	75	475	96	151	101	159	74	116	1.3
	78	500	102	161	106	167	81	127	0.6
B	80	525	107	169	111	175	87	137	0.23
	84	550	113	178	116	183	94	148	0.21
	86	575			121	190	101	159	0.20
	89	600			126	198	108	170	0.18
A	92	625*	Not determined				115	181	0.16
	95	650			131	206	122	192	0.14
	99	675			136	214	129	203	0.13
	101	700			141	222	136	214	0.12

* Glass scratching hardness commences here.

The printed capital letters in the zone column refer to special sections of zones of hardness as follows:

Zone	Brinell Ball Hardness Number		Scleroscope Hardness Number		Yield Point Tons per Square Inch		Maximum Stress Tons per Square Inch	
	From	To	From	To	From	To	From	To
F	150	200	34	34	20	32	36	46
E	200	300	50	50	32	56	46	66
D	300	400	64	64	56	79	66	86
C	400	500	78	78	79	102	86	106
B	500	600	89	89	102	...	106	126
A	600	700	..	.101	...	...	126	

COPPER ALLOYS

Strictly, a brass is a copper-zinc alloy containing one-third zinc and two-thirds copper; whereas a bronze is a copper-tin alloy containing approximately 10 per cent. tin and 90 per cent. copper. The old-style gun metal contained from 90 to 92 per cent. copper and from 8 to 10 per cent. tin. Lead is frequently added to both these classes of alloy to make them machine more easily, and both tin and zinc are commonly used in the same alloy, so that today we have a series of copper-tin-zinc alloys of almost infinite variety. In all cases in the useful alloys of this class, however, there is present more than 50 per cent. copper.

In most of the modern alloys tin is depended upon to give strength and zinc to cheapen the mixture. Some of the old-style gun metals contained as much as 16 per cent. tin and 84 per cent. copper, but such metals were brittle and hard. The common yellow brass employed by plumbers in making ordinary valves and fittings may be considered as composed of approximately 16 pounds copper, 8 pounds zinc, and $\frac{1}{2}$ pound lead. It will be noticed that this consists of approximately one-third zinc and two-thirds copper, with a little lead added to improve the machining qualities. For the making of high-grade casting ingots or new metal should be used in all cases. In making a brass the copper should be melted first and the zinc added, care being taken not to let the temperature rise too high, for if it does the zinc will ignite and burn. The lead is added last and the metal thoroughly stirred.

Composition of Bronzes (Navy Department)

	PARTS
White Metal:	
Tin	7.6
Copper	2.3
Zinc	83.3
Antimony	3.8
Lead	3.0
Hard Bronze for Piston Rings:	
Tin	22.0
Copper	78.0

Bearings—Wearing Surfaces, etc.:
- Copper 6
- Tin 1
- Zinc ..... ¼

Naval Brass:
- Copper 62.0
- Tin 1.0
- Zinc 37.0

Brazing Metal:
- Copper 85.0
- Zinc 15.0

Antifriction Metal:
- Copper—(best refined) 3.7
- Banca tin 88.8
- Regulus of antimony 7.5

Well fluxed with borax and rosin in mixing.

Bearing Metal—(Pennsylvania Railroad):
- Copper 77.0
- Tin 8.0
- Lead 15.0

NAVY DEPARTMENT SPECIFICATIONS FOR JOURNAL BRONZE (COMPOSITION H)

The chemical properties shall be as follows:

Copper, *Per Cent*	Tin, *Per Cent*	Zinc, *Per Cent*	Iron (Maximum), *Per Cent*	Lead (Maximum), *Per Cent*	Normal
82–84	12.5–14.5	2.5–4.5	0.10	1.0	83–13½–3½

Babbitt metal is named after its inventor, or first user, and the original proportions are supposed to be as follows:

Tin	Copper	Antimony
89.3	3.6	7.1
83.3	8.3	8.4
89.1	3.7	7.2

It is, when carefully prepared, one of the best metals in use for lining boxes that are subjected to a heavy weight and wear.

TEMPERS OF SHEET BRASS

Brass finished by annealing is designated as follows:
Light anneal or blued.
Drawing anneal or blued soft.
Soft drawing anneal or soft.
The first-named terms have been adopted by the S. A. E. and the A. S. T. M. and are to be preferred.

Brass finished by rolling is designated according to the amount the thickness of the sheet is reduced from the original thickness. When the thickness is reduced one number by the B. & S. gage the sheet is known as "¼ Hard." The sheet tempers follow.

Reduction in B. & S. Gage Numbers	Designation of Temper
1	¼ hard
2	½ hard
3	¾ hard
4	Hard
6	Extra hard
8	Spring
10	Extra Spring

Brass rods are usually drawn to what is called drill temper. It is produced by reducing the diameter from 5 to 10 per cent. Rods are also drawn "hard" by reducing the diameter from 12 to 20 per cent.

Tolerances allowed by the Chase Metal Works are SHEETS—0.00025 to 0.006 in. for B. & S. gages No. 38 to No. 0000 respectively. WIRE AND RODS—0.00025 in. for 0.025 in. rods to 0.010 in. for 3.5 in rods. TUBES—0.001 in. for 1 in. tubes of No. 26 gage to 0.031 in. for tubes 10 in. or over, of No. 0000 Stubbs gage.

TOLERANCES ON BRASS AND COPPER

Tolerances on sheet brass and copper depend on the width of the sheet as well as the thickness. On thicknesses from 0.460 to 0.324 inch (Nos. 0000 to 0) the tolerance is 0.005 inch on sheets up to 8 inches in width; 0.0055 inch on 8 to 11 inches in width; and 0.006 on width of 11 to 14 inches. The tolerances decrease to 0.00025, 0.0005 and 0.00075 inch respectively on sheets 0.0056 to 0.0040 inch thick (Nos. 35 to 38). These are B. & S. gage.

Wall thickness of seamless tubing is measured by Stubs gage. Tolerances vary both with wall thickness and tube diameter. On tubes under 2 inches diameter with walls 0.454 inch thick the tolerance is 0.019 inch. Tubes over 10 inches, with the same wall, is 0.031 inch. Tubes with a wall thickness of 0.083 inch have tolerances of 0.0045 inch for 2 inches and of 0.016 inch for 10 inches in diameter. Intermediate sizes and thicknesses vary in proportion. These tolerances are plus or minus (Chase Metal Works).

Common Uses and Tempers of Wrought-Copper Alloys

Straight Brasses

Common Mill Name	Approximate Composition Cu	Zn	Form	Typical Uses	Usual Temper
Copper	100		Sheet	Radiator cores	Soft
				Electrical	¼ hard and soft
			Wire	Electrical purposes	Soft
			Tube	Heater coils	Soft
				Gasoline supply	Soft
				Marine work	Blued or half hard
Gilding	95	5	Sheet	Screw shells	Blued
				Inexpensive jewelry	Blued
Commercial bronze	90	10	Sheet	Radiator cores	Soft
				Screw shells	Blued
				Kick plates	¼ hard
			Wire	Screws	Screw
				Rivets	Rivet
Rich low brass	85	15	Sheet	Hardware	Blued
Low brass	80	20	Sheet	Ornamental work	Blued
				Clock dials	¼ hard
Cartridge brass	70	30	Sheet	Cartridges	Blued soft
				Musical instruments	Blued soft
				Brazed tubes	Soft
				Spinning	Soft
				Springs	Spring
			Tube (usually brazed)	Bedsteads	Half hard
				Plumbers' bends	Blued soft
High brass	67	33	Sheet	Deep drawing	Blued or blued soft
				Spinning	Soft
				Eyelet	Blued soft
				Radiator cores	Blued
			Tube	Pump liners	Half hard
				Miscellaneous	Blued or half hard
Common high brass	65	35	Sheet	Drawing	Blued and blued soft
				Blanking	¼ hard
				Stamping	Soft
				Spring	Spring
			Wire	Screws	Screw
				Rivets	Rivet
				Safety pins	Spring
Pin metal	62	38	Wire	Pins	Extra hard
				Soft wire	Soft
				Brazing	Soft
Muntz metal	60	40	Tube	Condensers	Condenser
				Miscellaneous	Blued or half hard

Leaded Brasses

Common Mill Name	Approximate Composition			Form	Typical Uses	Usual Temper
	Cu	Zn	Pb			
Leaded yellow	66	33	0.8	Tube	For free turning	Half hard
Leaded high	66	33.5	0.4	Tube	Miscellaneous	Blued or half hard
Butt brass	64	35.25	0.75	Sheet	Butts	Half hard
					Hinges	¼ hard
					Matrices	Hard
				Wire	Screw eyes	Rivet
Clock brass	64	34	1¾	Sheet	Clock and watch backs, gears, etc.	Hard
Free turning	61	36	3	Rod	Most screw-machine work	Drill
Forging	60	38	2	Rod	Hot forgings	Drill

Tinned Brasses

	Cu	Zn	Pb	Sn			
Commercial bronze rod	86	12½	1	½	Rod	Hardware	Drill
Admiralty	70	29		1	Tube	Condenser tubes	Condenser
Naval brass	60	39		¾	Rod	Bolts and nuts	Drill
						Marine use	Drill
					Tube	Marine use	Blued

Nickel Silvers

	Cu	Zn	Ni			
5 per cent nickel	64	31	5	Sheet	Trimmings	Blued
				Wire	Inexpensive jewelry	Blued
10 per cent nickel	64	26	10	Sheet	Inexpensive jewelry	Blued
					Inexpensive tableware	Soft
18 per cent nickel	64	18	18	Sheet	Tableware	Soft
					Drawing	Soft
					Spinning	Soft
					Base for most silver-plated ware	Soft

APPROXIMATE AVERAGE PHYSICAL PROPERTIES OF WROUGHT-COPPER ALLOYS

Alloy	Composition				Density No. Cubic Inches	Tensile Strength		Per Cent Elongation		Scleroscope		Form in Inches
	Cu	Zn	Pb	Ni		Soft	Hard	Soft	Hard	Soft	Hard	Sheet
Copper	100				0.323	32,000	50,000	45	5	6	22	0.040
Gilding	95	5			0.320	34,000	52,000	45	5	6.5	24	0.040
Commercial bronze	90	10			0.318	36,000	56,000	45	5	7	26	0.040
Rich low brass	85	15			0.315	39,000	61,000	55	9	8	28	0.040
Low brass	80	20			0.313	42,000	66,000	62	12	9	32	0.040
Cartridge brass	70	30			0.308	44,000	68,000	70	11	9	32	0.040
High brass	67	33			0.306	43,000	67,000	70	10	9	32	0.040
Common high brass	65	35			0.305	42,000	66,000	70	10	9	32	0.040
Pin metal	62	38			0.304	48,000	75,000	50	5	11	35	0.040
Muntz metal	60	40			0.303	54,000	80,000	45	4	14	38	0.040
10 per cent Ni silver	64	26		10	0.310	58,000	80,000	40	10	15	35	0.040
18 per cent Ni silver	64	18		18	0.316	62,000	85,000	35	8	16	35	0.040
Forging brass	60	38	2		0.305	50,000	65,000	45	20			1-inch rod
Free turning	61	36	3		0.306	45,000	62,000	60	15			1-inch rod
Naval brass	60	39	Sn 1		0.304	54,000	70,000	50	25			1-inch rod

Bismuth Alloys (Fusible Metals)

	Bismuth	Lead	Tin	Cadmium	Melting Point
					C°
Newton's alloys ...	50.0	31.25	18.75	—	95
Rose's " ...	50.0	28.10	24.64	—	100
Darcet's " ...	50.0	25.00	25.00	—	93
Wood's " ...	50.0	24.00	14.00	12.00	66–71
Lipowitz's " ...	50.0	27.00	13.00	10.00	60

Alloys

	Copper	Tin	Lead	Zinc	Nickel	Antimony	
Babbitt	8.	92.				4.	Very hard.
Bell metal	76.5	23.5					"Big Ben,"
	74.8	25.2					Westminster.
Brass	63–72			27–34			Typical brass.
" wire	70.29	0.17		29.26			
Britannia	1.46	90.62				7.81	Birmingham sheet.
Bronze.....	95	4.		1.			British coinage.
	80–90	12–18		7.			Heavy bearings.
German silver..	60			20.	20		Nickel varies.
Gun metal	91	9.					Cannons.
Mannheim gold	80–88			20–12			
Muntz metal ..	60–62			38–40			Ship sheathing.
Packfong.....	43.8			40.6			Chinese alloy.
Shot metal			99.6		15.6		Trace of arsenic.
Speculum	70.24	29.11		trace			Telescope mirror.
Type metal....	2.0	10.	70			18.	
		3.2	82			14.	Stereotyping.
White metal ..	6.	82.				12.	For bearings.

Alloys for Coinage

	Gold	Copper	Silver	Other Constituents	Remarks
Gold coin	91.66	8.33	—	—	British standard.
" "	90.0	10.0	—	—	"Latin Union" and American.
" "	1.33	82.73	15.93	—	Roman, Septimus Severus, 265 A.D.
" "	40.35	19.63	40.02	—	Early British B.C. 50.
Silver coin	0.1	7.1	92.05	Lead 0.2	Roman B.C. 31, almost same as British silver coin.
" "	—	7.5	92.5	—	British standard.

Properties of Metals

Metal	Melting Point *	Wt. per Cu. In.	Wt. per Cu. Ft.	Tensile Strength	Specific Gravity	Chemical Symbol
Aluminum	1217	.0924	159.63	20,000	2.56	Al.
Antimony	1166	.2424	418.86		6.71	Sb.
Bismuth	520	.354	611.76		9.83	Bi.
Brass, cast	1692	.3029	523.2	24,000	8.393	
Bronze	1692	.319	550.	36,000	8.83	
Chromium	2750	.2457	429.49		6.8	Cr.
Cobalt	2714	.307	530.6		8.5	Co.
Copper	1981	.322	556.	36,000	8.9	Cu.
Gold	1945	.6979	1206.05	20,000	19.32	Au.
Iridium	4260	.8099	1400.		22.42	Ir.
Iron, cast	2700	.26	450.	16,500	7.21	Fe.
Iron, wrought	2920	.278	480.13	50,000	7.7	Fe.
Lead	621	.41	710.	3,000	11.37	Pb.
Manganese	2246	.289	499.4		8.	Mn.
Mercury	−38	.4909	848.35		13.59	Hg.
Nickel	2646	.3179	549.34		8.8	Ni.
Platinum	3191	.7769	1342.13		21.5	Pt.
Silver	1761	.3805	657.33	40,000	10.53	Ag.
Steel — cast	2450	.28	481.2	50,000	7.81	
Steel — rolled	2600	.2833	489.6	65,000	7.854	
Tin	449	.2634	455.08	4,600	7.29	Sn.
Tungsten	6152	.69	1192.31		19.10	W.
Vanadium	3128	.1987	343.34		5.50	V.
Zinc	787	.245	430.	7,500	6.86	Zn.

* Authority of U. S. Bureau of Standards.

Shrinkage of Castings

Aluminum — pure	.2031	inch per foot
" Nickel Alloy	.1875	" " "
" Special Alloy	.1718	" " "
Iron, Small Cylinders	.0625	" " "
" Pipes	.125	" " "
" Girders and Beams	.100	" " "
" Large Cylinders, Contraction of Diameter at Top	.0625	" " "
" Large Cylinders, Contraction of Diameter at Bottom	.083	" " "
" Large Cylinders, Contraction of Length	.094	" " "
Brass — Thin	.167	" " "
" Thick	.150	" " "
Copper	.1875	" " "
Bismuth	.1563	" " "
Lead	.3125	" " "
Zinc	.3125	" " "

METALS USED IN DIE CASTING

The metals used in die castings are limited by certain requirements peculiar to the process. Either they must not be subject to excessive shrinkage at high temperatures, or else they must be sufficiently strong to withstand the shrinkage. Unless one of these two conditions is met, the castings will crack before they can be removed from the die. For example, an alloy of aluminum and zinc, while common in sand casting, is not suited to die casting, although an alloy of aluminum and copper can be die-cast successfully. The metals used must not be such as will attack the surface of the die. It has been found that an alloy of copper and aluminum can be cast in permanent molds, while an alloy of copper and zinc, fusing at no higher temperature, will seriously injure the surface of the mold. The metals must fuse at a temperature low enough to avoid destroying the section of the casting machine in which the molten metal is contained, at least for a reasonable length of time. This condition has so far been one of the chief handicaps to the use of aluminum bronze in the production of die castings.

Die casting alloys, in general, may be divided into four groups:

1. Zinc-base alloys, which were early used in die casting, and which are still employed to a large extent in the production of many types of parts on account of their adaptability in taking accurate shapes when forced into the die under pressure. The two following formulas are representative of the alloys of this class now in use:

	Per Cent	Per Cent
Tin	6	None
Copper	3½	3
Aluminum	1¼	5
Zinc	89¼	*92

* Horsehead spelter or its equivalent should be used in this alloy, or, in fact, any zinc alloy where the aluminum content is higher than 1½ per cent.

2. Tin-base alloys, or, as they are more generally known, babbitt metals. They have become of special use in the production of automobile bearings and have also become commonly used in connection with various parts requiring acid-resistance or non-corrosive properties. The following formulas are representative of this class:

	Per Cent	Per Cent	Per Cent	Per Cent
Tin	87	84	81½	78½
Antimony	7	9	13¾	13¼
Copper	6	7	4¾	4¼
Lead				4

3. Lead-base alloys or alloys containing a high percentage of both tin and lead. They are also used for bearings, but where the speed is slower and the heat conditions less severe, for example, in stationary engines. The following alloys may be considered representative:

	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Lead	25	42	67½	75	84½
Tin	61½	48	17	15	5
Antimony	10½	8½	15	10	10
Copper	3	1½	00½	00	00½

4. Aluminum-base alloys. They may be divided into various groups: aluminum-copper, aluminum-silicon, aluminum-copper-silicon. Other elements, such as magnesium, manganese, and nickel, are sometimes introduced to give special color, toughness or wearing qualities.

In considering the various alloys used in die casting, the limits of weight, accuracy and other properties possible in each are of interest. They may be classified approximately as follows:

A—*Limits, Maximum Weights for Castings

	Pounds
Aluminum-base	3
Tin-base	8
Lead-base	10
Zinc-base	6

B—Limits, Minimum Wall Thickness

	Inch		Inch
Lead-base	1/32		
Tin-base	1/32		
Zinc-base	1/8	(on small castings)	1/16
Aluminum-base	1/8	(on small castings)	1/16

* These limits may sometimes be exceeded where the nature of the part is favorable to die casting.

C—Possible Variations from Drawing Dimensions, per Inch of Diameter or Length

	Inch
Lead-base	0.001
Tin-base	0.0005
Zinc-base	0.001
Aluminum-base	0.0025

Where the distance involved is several inches, these limits may sometimes be reduced.

D—Maximum Number of Threads

Lead-base, external	24 per inch
Zinc-base, external	30 per inch
Tin-base, external	34 per inch
Aluminum-base, external	20 per inch

In the case of aluminum where close fit is required, the threads should be cast oversize and chased. Where economical, internal threads may be cast in parts made from zinc-, tin- or lead-base alloys, but this is seldom possible in parts made of aluminum.

E—Holes

Lead-base, tin-base and zinc-base, $\frac{1}{32}$ inch minimum. Regulated by depth of hole and thickness of casting.

Aluminum-base, $\frac{3}{32}$ inch minimum. Size of hole is dependent on its length and the general design of castings. Holes not cast can usually be spotted to facilitate drilling.

F—Draft

Lead-base and tin-base. Cores 0.0005 inch per inch of length and diameter. Side walls 0.001 inch per inch.

Zinc-base. Cores 0.001 inch per inch of diameter and length. Side walls 0.001 inch per inch.

Aluminum-base. Cores 0.015 inch per inch of length and diameter. Cores less than $\frac{1}{4}$ inch in diameter should have 0.005 inch draft per inch of length. Side walls 0.005 inch per inch. It is sometimes possible to modify these limits when they interfere with the service required.

ALLOYS FOR SPECIAL PURPOSES

Alcumite

Alcumite is a non-ferrous alloy with a golden appearance. It melts at approximately 1900 deg. F. and remains strong and ductile up to about 1600 deg. Ultimate tensile strength is about 75,000 lbs. cast elongation about 25 per cent. In rolled form the tensile is 100,000 to 110,000 lbs. per sq. in. and the elongation 30 to 40 per cent. It resists sulphuric and most other corrosive acids and gases.

Alcumite is an aluminum bronze alloy with a copper base and some iron, manganese and nickel. It is malleable, can be ma-

chined at 80 ft. per minute, and welded. It can be cast and forged. Specific gravity 8.3, weight per cu. in. 0.299 lbs., melts at 1900° F. Shrinkage $\frac{1}{8}$ per ft. Brinnel hardness 130 for castings, 195 for hot rolled sheets. Tensile strength 75,000 lbs. for castings, 110,000 lbs. for hot rolled sheets.

Aluminum

Can be melted in ordinary plumbago crucibles the same as brass and will not absorb silicon or carbon to injure it unless overheated. Melts at 1217 degrees Fahr. or 625 Cent. Becomes granular and easily broken at about 1000 Fahr.

Shrinkage of pure aluminum.....	0.2031 inch per foot
Nickel aluminum casting alloy.....	0.1875 inch per foot
Special casting alloy.....	0.1718 inch per foot

The most used alloys have a strength of about 20,000 pounds to square inch at a weight of one-third that of brass.

Iron or sand molds can be used and should be poured as cool as it will run to avoid blowholes.

Burnishing.—Use a bloodstone or steel burnisher, with mixture of melted vaseline and kerosene oil or two tablespoonfuls of ground borax, dissolved in a quart of hot water and a few drops of ammonia added.

Frosting.—Clean with benzine. Dip in strong solution of caustic soda or potash, then in solution of undiluted nitric acid. Wash thoroughly in water and dry in hot sawdust.

Polishing.—Any good metal polish that will not scratch will clean aluminum. One that is recommended is made of

Stearic acid—One part
Fuller's earth—One part } Grind fine and mix very well.
Rotten stone—Six parts

Castings are cleaned with a brass scratch brush, run at a high speed. Sand blasting is also used both alone and before scratch brushing.

Spinning.—A high speed, about 4,000 feet per minute, is best for spinning. This means that for work 5 to 8 inches in diameter, 2,800 to 2,600 revolutions per minute is good, while for smaller work of 4 inches this would go up to 3,200 r.p.m.

Turning.—Use a tool with shearing edge similar to a wood-cutting tool, as they clear themselves better. Use kerosene or water as a lubricant, or if a bright cut is wanted, use benzine. For drawing on a press use vaseline.

Soldering.—See page 158.

Ascoloy

Ascoloy is a chromium steel alloy sometimes called rustless iron. It can be machined in about the same way as high carbon steel and can be welded by either oxyacetylene or arc, although the former is preferred. Tensile strength annealed, 80,000 lbs., properly heat-treated it has shown 200,000 lbs. Brinnel up to 364. Good for use in mines.

Bakelite

Bakelite is a synthetic product formed from formaldehyde and phenol or carbolic acid, that form a resin like material which hardens with heat. It is molded into many forms and by impregnating sheets of paper or cloth with the resin and baking it under pressure, a very strong sheet is produced. Gears are made from sheets made up of strong cotton duck and Bakelite and give quiet service and long life. Specific gravity 1.35. Tensile strength of average products 13,000 lbs. Molded products 4500 lbs.

Calite

Calite is a heat-resisting alloy in which nickel and aluminum are the principal alloys. It is used for carburizing boxes and similar purposes. Cast calite cannot be machined nor cut with the oxyacetylene torch. All finish is by grinding. It also resists corrosion from salts. The general physical properties are:

Melting point	2777 degrees Fahr.
Softening point	2500 degrees Fahr.
Working temperature	2200 to 2370 degrees Fahr.
Specific gravity	7.03
Weight per cubic inch	0.25 lb.
Tensile strength	36,800 pounds per square inch
Brinell hardness, annealed	286
Scleroscope	40

Duralumin

Duralumin is an aluminum alloy that has the advantage of being approximately one-third the weight of steel, or 0.101 to 0.103 pound per cubic inch. It can be supplied in various types and sections ranging from plates and sheets to angles and tubes, and can be cast, forged or stamped so that it may be used for a variety of parts. Duralumin is the trade name of the product, and similar metals are made under other names carrying the same characteristics.

Composition

The composition of the finished alloy can be stated as follows:

	Per Cent
Copper	3.5–4.0
Manganese	0.5–0.75
Magnesium	0.5–1.00
Silicon	Under 0.60
Iron	Under 0.60
Aluminum	Balance

Silicon and iron are generally impurities. The form in which the raw material is used is important and can be stated as follows:

Ingot aluminum over 99 per cent purity

Copper aluminum alloy	50 per cent copper 50 per cent aluminum
Aluminum magnesium	Aluminum 90 per cent Magnesium 10 per cent
Aluminum manganese	Aluminum 90 per cent Manganese 10 per cent

Annealing

Temperatures to which duralumin is subjected must be carefully watched and checked by the use of accurate pyrometers. The secret of good duralumin lies entirely with the accurate temperatures used in alloying and in heat treatments. Annealing should be done between the temperatures of 660 and 715 degrees Fahr. and cooled in air. At this temperature the metal becomes plastic and can be worked and formed into various shapes. The purpose of annealing is to increase the softness and ductility, so that it may be more easily formed into various shapes, such as stampings, also that it may withstand the strains to which it is to be subjected.

Heat Treatment

The tempering of duralumin consists of immersing the metal parts in a salts bath, heated to a temperature of 895 to 930 degrees Fahr. then quenching in boiling water. The salts employed are potassium nitrate and sodium nitrate in equal parts. An important point is the period of time necessary for the material to remain in the bath. For annealing plates from 0.04 to 0.08 inches thick, 10 to 20 minutes at 660 degrees Fahr. are required and for tempering the time is from 7 to 16 minutes at 930 degrees Fahr. The methods of heating are electrical, gas or oil. Charcoal or coke should never be used, because the gases given off, if they should combine with the nitrates used in the bath, would result in a highly combustible and explosive compound.

Machining

Duralumin can be turned and machined at practically the same speed and feed as brass. It does not seize or drag the tools as do some aluminum alloys. Kerosene forms a good tool lubricant in threading or finishing parts, leaving a clean-cut surface. A mixture of lard oil and kerosene, in equal parts, will be found useful for average work. When buffed, duralumin takes a fine polish similar to silver, except that the surface lasts longer, as it does not tarnish in the presence of sulphureted hydrogen and similar gases.

Everdur Metal No. 50

Everdur is an alloy of copper, silicon and manganese and compares physically with medium carbon steels, but resits corrosion. Specific gravity cast 8.15, weight per cu. in. 0.294 lb. Tensile strength, castings 50,000, small hard drawn wire 157,000 lbs. Melting point 1922° F. Machines similar to high grade bronze. Can be welded by either process.

Genelite

Genelite is a spongy bronze with about 40 per cent, by volume, of graphite uniformly distributed in it. Its spongy nature permits it to absorb about 3 per cent in weight or 20 per cent in volume, of oil. It is a bearing metal for piston pin bushings and similar places. It is difficult to cut as it dulls tools rapidly but can be easily ground with the proper wheels. It should be completely supported as it springs easily.

Mond "Seventy" Alloy

Mond seventy is a nickel copper alloy with a little manganese. Specific gravity 8.72, weight per cu. in. 0.314 lb. Anneals for general work at 1500° F. Can be welded by either method. Machines with high speed steel tools at about 60 ft. per min. Drill at regular speeds but ream at about 15 ft. per min. Strength runs up to 90,000 lbs.

Monel Metal

Monel metal is a natural alloy of copper and nickel which shows, when analyzed, a composition of 68 to 70 per cent nickel, about 1½ per cent iron and the remainder copper. It is practically non-corrosive from atmospheric influences, fresh or salt water or superheated steam, and is only slightly affected by acid fumes.

PHYSICAL PROPERTIES OF MONEL METAL

Yield point	58,760 pounds
Tensile strength	85,972 pounds
Elongation in 2 inches	38 per cent
Reduction in area	59 per cent
Melting point	1360°C. (2480°F.)
Specific gravity	8.87
Weight per cubic inch (cast)	0.319 pound
Weight per cubic inch (rolled)	0.323 pound

The metal is readily rolled into sheets and is used for a variety of purposes, such as roofing and cornice work, sheathing vessels, making cooking utensils, perforated screens and, in fact, for any purpose where non-corrosive sheet metal is particularly desired to meet special conditions. For estimating weights compare with copper, 0.322 pound; brass, 0.3029 pound; and steel, 0.28 pound per cubic inch.

Monel shrinks ¼ inch to the foot in casting; should be poured at 2800 degrees Fahr. Cores should be made of washed silica sand and raw linseed oil, about 25:1 for large cores and 60:1 for small cores.

PICKLE.—40 gallons cold water, 6 pounds sodium nitrate, 3 pounds sodium chloride, add 1 gallon of 66 degrees sulphuric acid last. Keep at 200 degrees for about 3 hours.

MACHINING.—Use high-speed steel with sharp cutting angles, as shown. High tungsten tools should be drawn to 1000 degrees Fahr. and cooled slowly.

Cutting speeds can be high for light cuts, as per table:

Cut, in Inches		1/32			1/16			1/8				1/4		
Feed, in Inches		1/64	1/32	1/16	1/64	1/32	1/16	1/64	1/32	1/16	1/8	1/32	1/16	1/8
Cutting Speed in Feet per Minute	Cast	100	90	75	85	70	50	75	60	45	40	50	40	30
	Rolled	115	100	85	95	80	55	85	70	50	45	55	45	35

Two turning tools and a threading tool are shown in Figs. 1, 2 and 3. Drills stand up at from 30 to 50 feet cutting speed and a feed of 0.005 inch per revolution. Milling cuts run from 70 to 80 feet per minute with $\frac{1}{8}$ inch cut and a feed of 0.005 to 0.01 inch feed

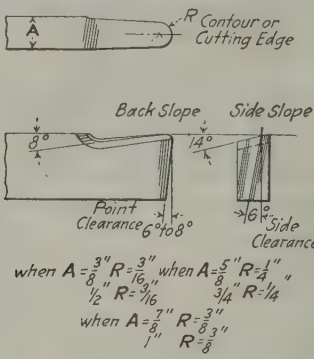


Fig. 1.—Tools for Monel Metal

per revolution. Taps work well at 15 to 20 feet per minute. Chip tends to stick to top and overheat. Taps with two or three lands and shallow flutes work well. Grinding is done much as with steel. Any good cutting oil is satisfactory. Forging temperatures range

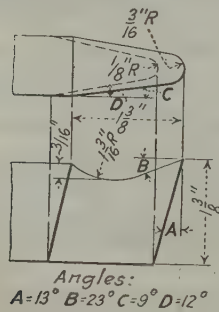


Fig. 2

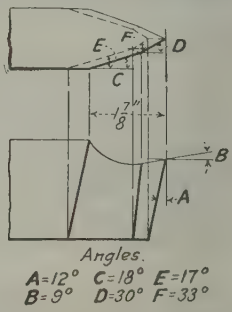


Fig. 3

from 1800 to 2100 degrees Fahr.—usually not over 1950 degrees Fahr. Forging presses not suitable. Anneal from 1450 to 1700 degrees Fahr. Heating in cyanide and cooling in water give soft, bright metal.

Welding.—Monel welds readily by gas or electric methods. Castings should be preheated to dull red. Welding tip should be one size larger than for steel and monel rods used. Monel can also be soldered and brazed in the usual manner, taking care to have metal clean at joints. Monel rods make weld on cast iron that is easily machined.

Drawing and Punching.—Reduction of diameter and depth of draw about as for steel, but corners of dies should have larger radius to prevent tearing. Metal is "sticky" and tends to adhere to soft dies. Diameter of first cup is usually about two-thirds that of blank. Reduction of 30 per cent in gage may be had in one draw with slight reduction in diameter. Clearance in dies depends on gage of metal, 0.004 inch being good for lighter gages. Has little tendency to wrinkle, but takes more power than steel. Anneal at 1400 degrees between draws. Punches ore designed about 75 per cent stronger than for steel, with same clearance angles.

Spinning and Polishing.—Owing to its toughness Monel is harder to spin than copper, brass, steel or silver, requiring more frequent annealing. Spinning tools should be brass, bronze or wood; steel has a tendency to drag and harden the metal more rapidly. Run lathe at about 600 r.p.m. and use tallow as lubricant.

In polishing it is necessary to get the skin off castings or hot-rolled metal. Five steps are advised: three grinding wheels, a grease wheel and a buff or polishing wheel.

Nichrome

Nichrome is a trade name for a specific mixture of nickel and chromium. It retains strength at high heats and resists continued or repeated exposure to heat, as in annealing and carburizing boxes; it also resists nitric, hydrochloric and sulphuric acids. Its properties are:

Tensile strength	64,000 pounds
Elongation in 2 inches	3½ per cent
Reduction in area	2 per cent
Melting point	2500 degrees Fahr.
Specific gravity	8.06
Weight per cubic inch (cast)	0.29 pound
Brinell hardness	157–187
Rockwell hardness	B-83–94
Scleroscope hardness	30

Nichrome welds readily by arc or flame. Preheating is necessary and the weld surface must be clean. Flux is needed in flame welding, but not in arc. Nichrome cannot be cut successfully with a torch, as it does not oxidize readily; a hack or cold saw is better and cheaper.

Nichrome castings can be machined readily with any good high-speed cutting steel at a speed of about 18 feet per minute. Due to the toughness of the alloy, the tools must be ground with special

angles. These particular angles have been worked out, and Fig. 4 shows how tools should be ground for machining and threading Nichrome and Cimet castings.

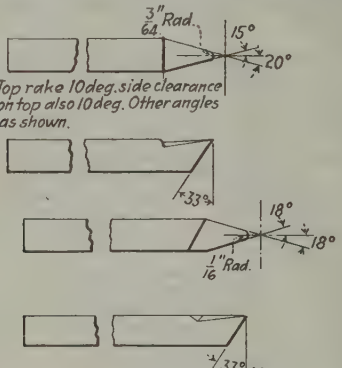


FIG. 4.—Tool for Nichrome

Silumin

Silumin is a German alloy of aluminum silicon, and has a strength of from 25,000 to 33,000 pounds per square inch with an elongation of 10 per cent. It shrinks very little in casting. The combination of high ductility with small shrinkage makes possible the production of very intricate castings. It has a specific gravity 10 per cent less than aluminum. Silumin has a very close grain and takes polish very well. It can be cut much faster than aluminum.

Stellite

Originated and developed by Elwood Haynes. Stellite is composed principally of cobalt and chromium, with small amounts of tungsten and molybdenum added to increase its hardness. It is not a steel in any sense since it contains absolutely no iron.

One of the most remarkable properties of stellite is its ability to retain a cutting edge at high temperatures so that lathe and planer speeds, which would be prohibitive when steel tools are used, may be employed.

It takes a very high polish which rivals silver in brilliancy and luster. Fruit juices, fruit acids, and antiseptic solutions, including bichloride of mercury, phosphoric acid, and iodine, have no effect on stellite, so that it is coming into use for pocket and table cutlery and surgeons' instruments.

All machining must be with grinding wheels and, because the material is cast in most cases, there is a fairly large amount of stock to be removed.

The turning tools are made in three grades: No. 1 stellite is the mildest, but also toughest and strongest; No. 2 stellite is harder than No. 1, but similar in other properties; No. 3 stellite is much harder than either of the other kinds and possesses great wearing qualities, but is quite brittle.

No. 1 is used for mild steel up to 30 point carbon, No. 2 for 30 to 100 point carbon and soft cast iron, and No. 3 for malleable iron and both hard and soft cast iron. Bar stellite as it comes from the mold must first be snagged to a more finished bar. The next step in making lathe tools is cutting off the bars to proper lengths.

STEAM HAMMERS AND DROP FORGING

WHILE it is impossible accurately to rate the capacity of steam hammers with respect to the size of work they should handle, on account of the greatly varying conditions, a few notes from the experience of the Niles-Bement-Pond Company will be of service.

For making an occasional forging of a given size, a smaller hammer may be used than if we are manufacturing this same piece in large quantities. If we have a 6-inch piece to forge, such as a pinion or a short shaft, a hammer of about 1100 pounds capacity would answer very nicely. But should the general work be as large as this, it would be very much better to use a 1500-pound hammer. If, on the other hand, we wish to forge 6-inch axles economically, it would be necessary to use a 7000- or 8000-pound hammer. The following table will be found convenient for reference for the proper size of hammer to be used on different classes of general blacksmith work, although it will be understood that it is necessary to modify these to suit conditions, as has already been indicated.

Diameter of Stock	Size of Hammer
3½ Inches	250 to 350 pounds
4 Inches	350 to 600 pounds
4½ Inches	600 to 800 pounds
5 Inches	800 to 1000 pounds
6 Inches	1100 to 1500 pounds

Steam hammers are always rated by the weight of the ram and the attached parts, which include the piston and rod, nothing being added on account of the steam pressure behind the piston. This makes it a little difficult to compare them with plain drop or tilting hammers, which are also rated in the same way.

Steam hammers are usually operated at pressures varying from 75 to 100 pounds of steam per square inch, and may also be operated by compressed air at about the same pressures. It is cheaper, however, in the case of compressed air to use pressures from 60 to 80 pounds instead of going higher.

In figuring on the boiler capacity for steam hammers, there are several things to be considered, and it depends upon the number of hammers in use and the service required. It will vary from one boiler horse-power for each 100 pounds of falling weight up to three horse-power for the same weight, according to the service expected. In a shop where a number of steam hammers are being used, it is usually safe to count on the lower boiler capacity given, as it is practically safe to say that all of the hammers are never in use at the same time. In a shop with a single hammer, on the other hand, and especially where hard service is expected, it is necessary to allow the larger boiler capacity as there is no reserve to be drawn on, due to part of the hammers being idle, as in the other case.

DRAFT IN DROP FORGING DIES

In sinking dies for drop forging, it is important that the draft at the sides of the impression should be made as little as possible to avoid heavy cuts in the machining operations. It is equally important that the draft be sufficient to allow the forging to be easily withdrawn from the die, else production under the hammer will be hampered. The standard draft (or draw) for most dies is 7 degrees from the perpendicular, but other angles are used in special cases and sometimes two or three different angles of draft are used in the same die at different parts of the impression.

Figure 1 shows the plan and side elevation of a lower die where three angles of draft are advisable. The shoulders *A* and *B* are places where the metal is likely to hug on account of the contraction

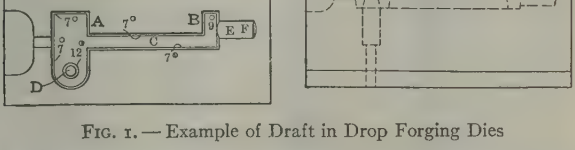


Fig. 1. — Example of Draft in Drop Forging Dies

of the hot metal along the part marked *C*, which is of comparatively small cross-section and will cool rapidly. These shoulders are given an angle of 9 degrees. The inserted tool-steel plug *D*, is another place where metal is likely to hug badly. It is usual to give such plugs 12 and even 15 degrees of draft on each side. Moreover, the tendency of plugs to get "jumped up," hammered over and badly heat checked is much reduced if they are given a big draft. The part marked *E* is semicircular and will draw easily. The end of *E* at *F* is a part of a sphere. All other sides of the impression are given 7 degrees draft. If the die is smooth and regular the forging will draw easily.

All impressions are laid out to $\frac{1}{8}$ inch to the foot shrink rule. This allows for a shrinkage of about 0.010 inch to the inch. The same shrinkage is allowed in the thickness of forgings. For example: A forging is to be 2 inches thick with half the thickness in each die. The depth of impressions will be 1.010 inch in each die. In laying out the impression on the face of the die, allowance has been made for shrinkage in length, thickness and breadth of forging, and, in addition, for the draft on the sides. In complex dies where there are many different depths and offsets on the face of the die, the die sinker has to keep all these points constantly in mind while laying out, or run the risk of spoiling the whole job.

A Table of Draft Dimensions

The allowance for 7-degree draft is easy to remember, being almost exactly $\frac{1}{32}$ inch at the face of the die for each $\frac{1}{4}$ inch of depth. Table 1 has been calculated to give the allowances in thousandths

of an inch on actual depth, as measured with an ordinary depth gage. It is not usual in marking out to work closer than $\frac{1}{64}$ inch, but the arrangement of table in thousandths allows the nearest $\frac{1}{64}$ inch

TABLE 1.—ALLOWANCE IN THOUSANDTHS OF AN INCH AT FACE OF DIE FOR STANDARD ANGLES OF DRAFT AND VARIOUS DEPTHS OF IMPRESSION

Depths in Inches	STANDARD DRAFT ANGLES IN DEGREES			
	5 Degrees	7 Degrees	9 Degrees	12 Degrees
	Inch	Inch	Inch	Inch
$\frac{1}{4}$	0.011	0.015	0.020	0.027
$\frac{3}{8}$	0.022	0.031	0.040	0.053
$\frac{1}{2}$	0.033	0.046	0.059	0.080
$\frac{5}{8}$	0.044	0.061	0.079	0.106
$\frac{3}{4}$	0.055	0.077	0.099	0.133
$\frac{7}{8}$	0.066	0.092	0.119	0.159
1	0.077	0.107	0.139	0.186
1	0.087	0.123	0.158	0.213
$1\frac{1}{8}$	0.098	0.138	0.178	0.239
$1\frac{1}{4}$	0.109	0.153	0.198	0.266
$1\frac{3}{8}$	0.120	0.169	0.218	0.292
$1\frac{1}{2}$	0.131	0.184	0.238	0.319
$1\frac{5}{8}$	0.142	0.200	0.257	0.345
$1\frac{3}{4}$	0.153	0.215	0.277	0.372
$1\frac{7}{8}$	0.164	0.230	0.297	0.399
2	0.175	0.246	0.317	0.425

to be taken. The best plan is to take the allowance for the angle at 1 inch depth as a constant and figure out the allowance for the particular depth wanted from the expression

$$Draft\ allowance = \frac{C\,D}{1}.$$

Where C = a constant and D = the depth in inches.

MAKING TYPES

A type, shown in Fig. 2, is generally used as a guide for chipping and scraping out the spherical end of the semicircular part E. It is

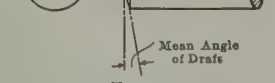


FIG. 2

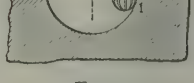


FIG. 3

not usual to make the curve on the end conform to any particular mean angle of draft. Most diesinkers merely turn the end of the type to a curve that looks right to the eye. However, uniformity is desirable in these curves and Table 2 is given as a help in that direction. It gives the values of the mean angle of draft with various radii expressed in terms of the diameter of the type. It will

TABLE 2.—MEAN DRAFT OF SPHERICAL END OF CYLINDRICAL TYPE

When Radius of End of Type is	Mean Angle of Draft in Degrees is
$2\frac{1}{2}$ × Diameter of Type	$5\frac{3}{4}$
$2\frac{1}{4}$ × " " "	$6\frac{1}{2}$
2 × " " "	$7\frac{1}{4}$
$1\frac{3}{4}$ × " " "	$8\frac{1}{4}$
$1\frac{1}{2}$ × " " "	$9\frac{1}{2}$

be noted that if the radius r is made twice the diameter of the type the mean angle of draft is $7\frac{1}{4}$ degrees. This rule is easy to remember and a good one to adopt as standard. A good and easy way to get a close approximation to the required curve is as follows: Turn a cylinder of tool steel to the required diameter. Face the end square, scratch off the distance $G\,H$ equal to the allowance for draft obtained from Table 1, remembering that the depth is half the diameter of the type. Turn the end to a curve which is uniform to the eye from the center to the scratched line H. After the type is hardened it is ready for use.

Semicircular impressions are finished with ball cutters of the correct diameter. When a ball cutter of the correct diameter is not at hand and the job will not warrant making one, the following method may be used. The center line of the impression is projected to the end of the die. A semicircle is scribed on the vertical surface of the end. After the impression is roughed out, a smaller ball cutter is placed in the chuck of a diesinking machine and the knee and slides manipulated until the cutter is in proper relation to the semicircle as shown in Fig. 3. A square is used to indicate when the curves of cutter and semicircle are coincident, as at I. The micrometer dials are now set, the lateral slide locked, the knee lowered, the longitudinal slide operated until the cutter is in position over the impression and the ball tool sunk into the die until the micrometer comes to the position set at the semicircle on the end. A longitudinal cut is taken with this setting. The cutter is then placed in another lateral position and the operation of setting and cutting repeated. It may be necessary to perform this operation several times, and even then the result will be a series of gutters and ridges instead of a uniform, semicircular depression. This can be readily corrected with the scraper and riffler.

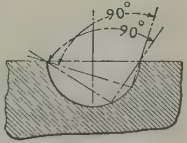


FIG. 4

An aid in testing the accuracy of semicircular impressions is shown in Fig. 4. If the semicircle is true, the corners of the square will touch in all positions when the sides are resting on the edges of the impression. If the square rocks on the corner in any position, that spot is high and must be scraped down. This test must be made before the "flash" is milled in the die.

KNOTS AND SLINGS FOR HANDLING WORK

THE knots described have been useful in work in out-of-the-way places. No. 1 indicates the meaning of the terms employed.

No. 2, Simple or Overhand Knot.—The simplest of all knots to tie, and may be used as a stop on a rope. A free end is necessary to make it. If strained, it injures the fiber of the rope more than a figure-8 knot, and it is difficult to unmake and liable to jam.

No. 3, Double Overhand Knot.—Used for the end of a rope when it is required to prevent its going through an eye, as in a pulley block or for the end of a halter rope. Also useful for shortening a rope and may be made with any number of turns: *A* in the illustration shows the first position; *B*, the knot finished with two turns; and *C*, one with four full turns of rope.

No. 4, Figure-8 Knot (Flemish).—May be employed as a stop on a rope; is less injurious to the fiber of the rope, and more easily undone than either the single or double overhand knot. If made with the rope doubled and the bight left long, it becomes a figure-8 hoop knot.

No. 5, Stevedore Knot.—End of the rope is wrapped twice around the standing and then passed through the eye. Useful as a stop on a rope to prevent the end going through an eye, as in a pulley block (see double overhand knot). Also employed instead of sewing the rope end with twine.

No. 6, Boat Knot (Marline-spike Hitch).—Suitable for quickly making a rope ladder, or getting a temporary pull on a rope with a marline-spike. No free ends required to form this knot. Point marked *A* must always be at the back of the spike or rung of the ladder, away from the direction of the weight or pull.

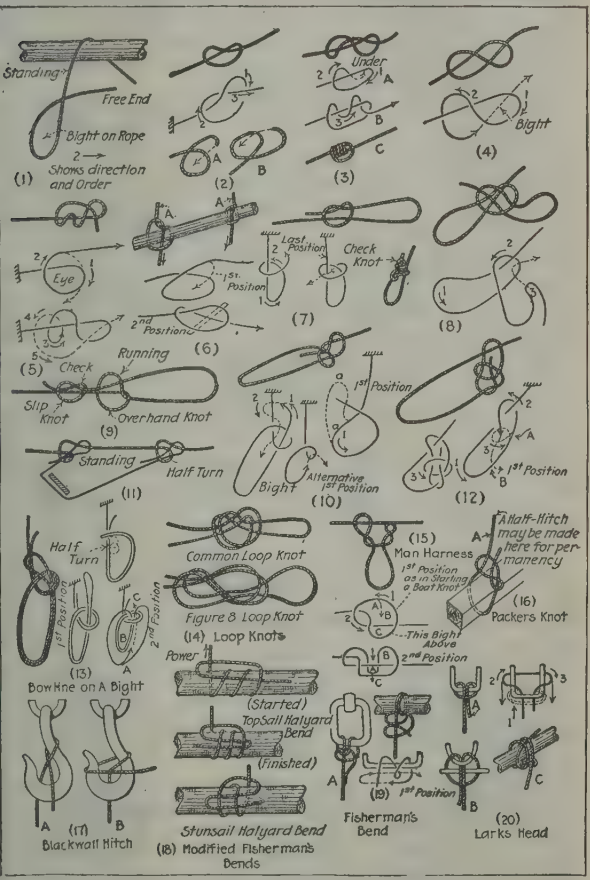
No. 7, Slip Knot (Simple Running Knot).—The simplest kind of slip knot. It may be used similarly to the packer's knot, but is not so good, as it is liable to pull through and does not bind on the rope.

No. 8, Tomfool Knot (Double Running Knot).—When the loops are drawn taut and the ends tied, this makes a pair of handcuffs which it is almost impossible for the person so secured to undo. It may be used as a barrel sling, half-hitches being put on the ends, and the hook put under the knot itself. The bight marked 3 is passed through the overhand loop as shown by the dotted line.

No. 9, Flemish Loop.—This knot makes a simple loop for light work and may be used in the same way as a bowline, but is not so quickly made; neither is it so secure nor so easily undone. The security depends almost entirely upon the check knot.

No. 10, Bowline.—A generally useful knot when a loop of any sort that will not slip is required, as in a sling for lowering a man, or fastening a bucket to a rope.

No. 11, *Bowline II.*—A method of attaching the end of one rope to the standing of another. A half turn is put in the standing and



the end of the other rope taken through as if tying an ordinary bowline. This knot is practically a sheet bend.

No. 12, *Running Bowline.*—As shown in the first position a half turn is made at *A* (shown dotted) and the end is passed through and

to the back of the part marked *B*. This is a good slip knot and does not tighten on the standing, always remaining open.

No. 13, *Bowline on a Bight.*—The part marked *A* is passed behind *B* and then in the direction of the arrow to *C*. The bight *B* is then pulled taut. The two loops of this knot may be used as a man sling, a barrel sling, or as a double man-harness, one loop under each shoulder. When tightened it will not slip.

In case of an injured man, one of the loops can be kept shorter than the other and adjusted under the armpits, the man being seated in the larger loop.

No. 14, *Open-hand Loop Knot and Figure-8 Loop Knot.*—The upper loop knot is the one in common use and is adapted principally for small ropes. The lower, or figure-8 knot, is a better form and may be used on a larger rope as it injures the fiber less than the common form. These knots require a greater length of rope than the bowlines, but may be used in similar ways.

No. 15, *Man-harness Knot.*—This knot can be tied in a rope with neither end free. The bight *A* is pulled through under *B* and over *C*, and the knot pulled taut. It is useful as allowing a number of men to get a good purchase on a rope for hauling; also to put loops in the rope to receive hooks at points other than the ends.

No. 16, *Packer's Knot.*—A modification of a simple slip knot, but has the advantage, when pulled tight, of biting on the standing at *A* and not easily slipping back. It is particularly useful for cording up rolls of camp bedding, etc. It can be made permanent by an added half hitch on the standing.

No. 17, *Blackwall Hitch.*—A convenient method for returning an empty rope on a hook. With a greasy rope, method *B* holds better.

No. 18, *Modified Fisherman's Bends.*—These are given as alternatives for securing ropes to poles or bars, and are adapted to heavy strains.

No. 19, *Fisherman's Bend.*—A better method than the gooseneck or lark's head (Fig. 20) for securing rope a to a chain or link. It is also used to fasten the rope to a bar or the bail of a bucket. Lashing at *A* is necessary to prevent pulling through. As shown in first position, two turns are taken over the link and the end brought back in front and passed through the turns as shown dotted.

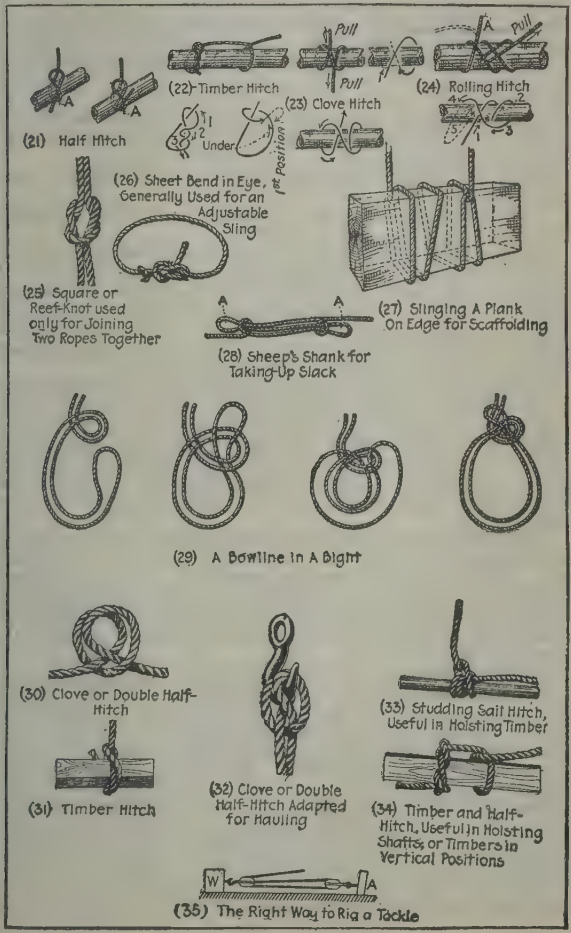
No. 20, *Lark's Head.*—Useful for fastening a rope to the link of a chain or to a ring in a wall or box. It is not a secure knot unless lashed at *A*. *B* shows a toggle inserted to prevent slipping. *C* is a modified gooseneck on a bar, suitable for securing the end of a rope in scaffolding. The end must be placed at the back and the whole pulled taut.

No. 21, *Half Hitch.*—A quick and simple way of securing a rope to a timber when no great pull is expected. The rope end is placed under the pole, then back over to the right as shown. The end must always be placed right at the back away from the pull, as shown at *A*. The right-hand sketch shows the hitch with a slip to facilitate undoing.

No. 22, *Timber Hitch.*—This is the best and simplest of all timber hitches and may be used for towing or otherwise handling timber, rods, pipes, etc.; also for starting lashings on scaffolding or any

kind of pole work. For raising or lowering timber, the half hitch should be placed high above the center of gravity to avoid slanting.

No. 23, Clove Hitch.—This is one of the most useful of all hitches, as it will take a strain in either direction without slackening. It is



used for mooring ships heads of derricks for guy lines and all kinds of rigging work. It may be easily undone, or a bight may be put in instead of one end to use as a slip. When commencing to tie the hitch on a horizontal bar, the rule is over and back below, or the reverse of the procedure in tying a half hitch.

No. 24, *Rolling Hitch.*—This lashing is used for getting a grip on a large rope with a smaller one. Made in a chain it can be applied to wire ropes and will not slip when the load has been taken up. It is also suitable for hauling on electric cables, or withdrawing diamond drill or other rods. For securing the end *A* may be brought down and be lashed to the large rope. In making, the end is passed over the spar twice, then returned back as shown at (3), then over behind as at (4), and up and under as at (5).

No. 25.—A square or reef knot, used only for joining two ropes together.

No. 26.—Sheet bend in an eye, generally used for an adjustable sling.

In supporting a swinging scaffold, it is often advantageous to use light material, while, at the same time, strength is required. A plank on edge is a great deal stiffer than the same plank laid flat, and No. 27 shows how to sling a plank edgewise by a rope so that it will stay. The knot used is a very simple one. A clove hitch is made around the end of the plank; then one of the parts is twisted around the plank until the ends lead as shown in the sketch.

Very often it is desirable to shorten a piece of rope without cutting it. No. 28 shows a sheep's shank which is used for this purpose. The rope is brought back on itself, making two or more bights, and a half hitch is taken around each bight. This knot will not slip, and will nearly fall apart of its own accord if the strain is released, so that when there is a liability of this happening, it is well to pass a piece of wood through the loop *A* at each end and pull the rope tight on them.

One of the handiest knots to know is a bowline. The bowline will not slip, and is easy to untie. It can also be tied in the bight of a rope, and is then called a "bowline in a bight." The steps required to tie it are shown at No. 29. It is particularly handy when it is necessary to hitch an auxiliary tackle on a fall to get additional purchase for a heavy lift. This knot has all the good points of the simple bowline.

In using a block and fall for pulling things, there is a right way and a wrong way of doing it. No. 35 shows the right way, *W* being the weight to be moved. If *A* were the weight and *W* the post, the blocks being left as shown, then it would be wrong. The advantage of the right way of doing it is that the leverage due to one additional part of rope in the tackle is gained. Thus a three-part fall, rigged in the right way, is as good as a four-part fall rigged in the wrong way, and has the additional advantage that there is one less sheave with its friction. In lifting a heavy weight, it is sometimes desirable to put a tackle on the fall to gain additional leverage; the common practice in a case of this kind is to hitch the auxiliary tackle to a "dead man." The right way is to hitch this tackle to the piece to be lifted alongside the main tackle, which adds considerably to the

leverage, being equivalent to one more part to the main fall besides the gain by the use of the auxiliary fall.

No. 30.—Clove or double half hitch.
No. 31.—Timber hitch.
No. 32.—Clove or double half hitch as used for hauling.
No. 33.—Studding sail hitch as used in hoisting timber.
No. 34.—Timber and half hitch. Useful in hoisting shafting or timber in a vertical position.

SAFE LOADS FOR EYE-BOLTS AND FOR ROPES AND CHAINS

TABLE 1.—SAFE LOADS FOR EYE-BOLTS

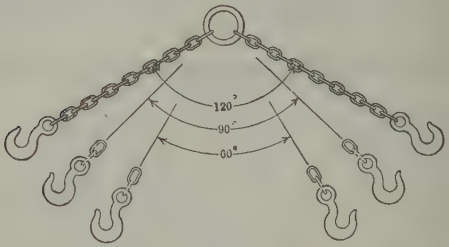
	Threaded Diam.	Inside Diam. of Eye	Diam. Metal Around Eye	Safe Load, Lb.
Drop-forged steel	½	1 ½	⅞	1,100
	⅝	1⅞	1⅛	1,500
	¾	2⅛	1⅜	1,800
	⅞	2⅜	1⅝	2,800
	1	2⅝	1⅞	3,900
	1 ¼	3⅛	2⅜	5,100
	1 ½	3⅝	2⅞	8,400
	1 ¾	4⅛	3⅜	12,200
	2	4⅝	3⅞	16,500
	2 ¼	5⅛	4⅜	21,800
D.B.G. iron E.L., 28,000 lb. per sq. in., welded	1 ½	3	1 ½	10,000
	1 ¾	4	1 ½	11,000
	2	5	1 ½	14,000
	2 ½	6	2	16,000

TABLE 2.—SAFE LOADS ON ROPES AND CHAINS

Manila Rope, Safe Load in Tons				Wire Cable, Safe Load in Tons				Chains, Safe Load in Tons			
Diam. of Rope, In.	Single Rope	Two Part	Four Part	Diam. of Cable, In.	Single Rope	Two Part	Four Part	Diam. of Chain, In.	Single Chain	Two Part	Four Part
½	¼	½	¾	½	1	2	3½	½	½	¾	1½
⅝	½	¾	1	⅝	1¾	3½	6½	⅝	1	1¾	3
¾	¾	1	1¼	¾	2½	4½	9	¾	2	3½	6
⅞	1	1¼	2	⅞	3¼	6	12	⅞	3	5	9
1	1¼	1½	2½	1	4	8	16	1	5	9	15
1¼	1	2	3	1¼	6	12	24	1¼	6	10½	18
1½	1½	2½	4	1½	10	19	36	1½	8	14	24
1⅝	2	4	6	1⅝	13	25	48	1⅝	11	19	33
2	2½	5	8	2	16	32	60	1¾	13	23	39
2¼	3½	6½	11					1½	18	32	54
2½	4½	8	13								

Safe Loads in Pounds for Double-chain Slings

When lifting with a double sling the load varies with the angle as shown in the table which gives the safe load of chain at the various angles shown. At an angle of 120 degrees the load is doubled. Never tie knots in chains, take up slack with adjusters or wedges.



Size of Chain	Maximum	60°	90°	120°
¼ Inch	2000	1720	1400	1000
5/16 "	2930	2500	2040	1460
3/8 "	4260	3660	2980	2130
7/16 "	6000	5160	4200	3000
½ "	8000	6880	5600	4000
¾ "	12320	10600	8620	6160

GENERAL REFERENCE TABLES

COMMON WEIGHTS AND MEASURES

Linear or Measure of Length

12 inches = 1 foot. 3 feet = 1 yard.
5½ yards = 1 rod. 40 rods = furlong.
8 furlongs = 1 mile.

Equivalent Measures

Inches		Feet		Yards		Rods		Furlongs		Mile
36	=	3	=	1						
198	=	16.5	=	5.5	=	1				
7920	=	660	=	220	=	40	=	1		
63,360	=	5280	=	1760	=	320	=	8	=	1

Square Measure

144 square inches = 1 sq. foot. 30¼ square yards = 1 sq. rod
9 square feet = 1 sq. yd. 160 square rods = 1 acre.
640 acres = 1 sq. mile.
1 acre = 43,560 sq. ft. = 208.7 ft. on side.
10 acres = 660 sq. ft.

Equivalent Measure

Sq. Mi.		A.		Sq. Rd.		Sq. Yd.		Sq. Ft.		Sq. In.
1	=	640	=	102,400	=	3,097,600	=	27,878,400	=	4,014,489,600
		1	=	160	=	4480	=	43,560	=	6,272,640

Cubic Measure

1728 cubic inches = 1 cubic foot. 128 cubic feet = 1 cord.
27 cubic feet = 1 cubic yard. 24¾ cubic feet = 1 perch.
1 cu. yd. = 27 cu. ft. = 46,656 cu. in.

Weight—Avoirdupois

437.5 grains = 1 ounce. 100 pounds = 1 hundred weight.
16 ounces = 1 pound. 2000 pounds = 1 ton.
2240 pounds = 1 long ton.
1 ton = 20 cwt. = 2000 lbs. = 32,000 oz. = 14,000,000 gr.

Weight = Troy

24 grains = 1 pennyweight. 20 pwt. = 1 ounce.
12 ounces = 1 pound.
1 lb. = 12 oz. = 240 pwt. = 5760 gr.

Dry Measure

2 pints = 1 quart. 8 quarts = 1 peck.
4 pecks = 1 bushel
1 bu. = 4 pk. = 32 qt. = 64 pt.
U. S. bushel = 2150.42 cu. in. British = 2218.19 cu. in.

Liquid Measure

4 gills = 1 pint. 4 quarts = 1 gallon.
2 pints = 1 quart. 31½ gallons = 1 barrel.
2 barrels or 63 gals. = 1 hogshead.
1 hhd. = 2 bbl. = 63 gals. = 252 qt. = 504 pt. = 2016 gi.

The U. S. gallon contains 231 cu. in. = .134 cu. ft.
One cubic foot = 7.481 gallons.
One cubic foot weighs 62.425 lbs. at 39.2 deg. Fahr.
One gallon weighs 8.345 lbs.
For rough calculations 1 cu. ft. is called 7¼ gallons and 1 gallon as 8⅓ lbs.

Angles or Arcs

60 seconds = 1 minute. 90 degrees = 1 rt. angle or quadrant.
60 minutes = 1 degree. 360 degrees = 1 circle.
1 circle = 360° = 21,600′ = 1,296,000″.
1 minute of arc on the earth's surface is 1 nautical mile = 1.15 times a land mile or 6080 feet.

Weight of a Cubic Foot of Substances

Names of Substances	Average Weight, Lbs.
Anthracite	
" broken, loose	54
Ash, American white, dry	38
Brass (Copper and Zinc), cast	504
" rolled	524
Brick, best pressed	150
" common hard	125
Brickwork, pressed brick	140
" ordinary	112
Cement, hydraulic, ground, loose, American, Rosendale	94
" " " " English, Portland	90
Cherry, dry	42
Chestnut, dry	41
Coal, bituminous	
" " broken, loose	49
Coke, loose, of good coal	27
Copper, cast	542
" rolled	547
Ebony, dry	76
Elm, dry	35

WEIGHT OF A CUBIC FOOT OF SUBSTANCES—*Continued*

NAMES OF SUBSTANCES	Average Weight, Lbs.
Glass, common window	157
Gold, cast, pure, or 24 carat	1204
Granite	170
Gravel, about the same as sand	
Hemlock, dry	25
Hickory, dry	53
Ice	58.7
Iron, cast	450
" wrought, average	480
Lead	711
Lignum Vitæ, dry	83
Lime, quick, ground, loose, or in small lumps	53
Limestones and Marbles	168
Mahogany, Spanish, dry	53
Maple, dry	49
Marbles, see Limestones.	
Masonry, of granite or limestone, well dressed	165
Mercury, at 32° Fahrenheit	849
Mica	183
Oak, white, dry	52
" other kinds	32 to 45
Petroleum	55
Pine, white, dry	25
" yellow, Northern	34
" " Southern	45
Platinum	1342
Rosin	69
Salt, coarse, Syracuse, N. Y.	45
Sand, of pure quartz, dry, loose	90 to 106
Sandstones, fit for building	151
Silver	655
Slate	175
Spruce, dry	25
Steel	490
Sulphur	125
Sycamore, dry	37
Tin, cast	459
Walnut, black, dry	38
Water, pure rain or distilled, at 60° Fahrenheit	62.48
" sea	64
Wax, bees	60.5
Zinc or Spelter	437

Green timbers usually weigh from one-fifth to one-half more than dry.

THE METRIC SYSTEM

The Metric System is based on the Meter which was designed to be one ten-millionth ($\frac{1}{10000000}$) part of the earth's meridian quadrant, through Dunkirk and Formentera. Later investigations, however, have shown that the Meter exceeds one ten-millionth part by almost one part in 6,400. The value of the Meter, as authorized by the U. S. Government, is 39.37 inches. The Metric system was legalized by the U. S. Government in 1866.

The three principal units are the Meter, the unit of length, the liter, the unit of capacity, and the gram, the unit of weight. Multiples of these are obtained by prefixing the Greek words: deka (10), hekto (100), and kilo (1000). Divisions are obtained by prefixing the Latin words: deci ($\frac{1}{10}$), centi ($\frac{1}{100}$), and milli ($\frac{1}{1000}$). Abbreviations of the multiples begin with a capital letter, and of the divisions with a small letter, as in the following tables:

Measures of Length

10 millimeters (mm)	=	1 centimeter	cm.
10 centimeters	=	1 decimeter	dm.
10 decimeters	=	1 meter	m.
10 meters	=	1 dekameter	Dm.
10 dekameters	=	1 hektometer	Hm.
10 hektometers	=	1 kilometer	Km.

Measures of Surface (not Land)

100 square millimeters (mm^2)	=	1 square centimeter	cm^2.
100 square centimeters	=	1 square decimeter	dm^2.
100 square decimeters	=	1 square meter	m^2.

Measures of Volume

1000 cubic millimeters (mm^3)	=	1 cubic centimeter	cm^3.
1000 cubic centimeters	=	1 cubic decimeter	dm^3.
1000 cubic decimeters	=	1 cubic meter	m^3.

Measures of Capacity

10 milliliters (ml)	=	1 centiliter	cl.
10 centiliters	=	1 deciliter	dl.
10 deciliters	=	1 liter	l.
10 liters	=	1 dekaliter	Dl.
10 dekaliters	=	1 hektoliter	Hl.
10 hektoliters	=	1 kiloliter	Kl.

Note. — The liter is equal to the volume occupied by 1 cubic decimeter.

Measures of Weight

10 milligrams (mg)	=	1 centigram	cg.
10 centigrams	=	1 decigram	dg.
10 decigrams	=	1 gram	g.
10 grams	=	1 dekagram	Dg.
10 dekagrams	=	1 hektogram	Hg.
10 hektograms	=	1 kilogram	Kg.
1000 kilograms	=	1 ton	T.

Note.—The gram is the weight of 1 cubic centimeter of pure distilled water at a temperature of 39.2°F., the kilogram is the weight of 1 liter of water; the ton is the weight of 1 cubic meter of water.

METRIC AND ENGLISH CONVERSION TABLE

Measures of Length

1 meter = { 39.37 inches. / 3.28083 feet. / 1.0936 yds.
1 centimeter = .3937 inch.
1 millimeter = { .03937 inch, or / 1/25 inch nearly.
1 kilometer = 0.62137 mile.

1 foot = .3048 meter.
1 inch = { 2.54 centimeters. / 25.4 millimeters.

Measures of Surface

1 square meter = { 10.764 square feet. / 1.196 square yds.
1 square centimeter = .155 sq. in.
1 square millimeter = .00155 sq. in.

1 square yard = .836 square meter.
1 square foot = .0929 square meter.
1 square in. = { 6.452 sq. centimeters: / 645.2 sq. millimeters.

Measures of Volume and Capacity

1 cubic meter = { 35.314 cubic feet. / 1.308 cubic yards. / 264.2 gallons (231 cubic inch).
1 cubic decimeter = { 61.023 cubic in. / .0353 cubic ft.
1 cubic centimeter = .061 cubic inch.
1 liter = { 1 cubic decimeter. / 61.023 cubic inches. / .0353 cubic foot. / 1.0567 quarts (U. S.) / .2642 gallons (U. S.) / 2.202 lbs. of water at 62° F.

1 cubic yard = .7645 cubic meter.
1 cubic ft. = { .02832 cubic meter. / 28.317 cubic decimeters. / 28.317 liters.
1 cubic inch = 16.387 cubic centimeters.
1 gallon (British) = 4.543 liters.
1 gallon (U. S.) = 3.785 liters.

Measures of Weight

1 gram = 15.432 grains.
1 kilogram = 2.2046 pounds.
1 metric ton = { .9842 ton of 2240 lbs. / 19.68 cwts. / 2204.6 lbs.

1 grain = .0648 grams.
1 ounce avoirdupois = 28.35 grams.
1 pound = .4536 kilograms.
1 ton of 2240 lbs. = { 1.016 metric tons. / 1016 kilograms.

Miscellaneous Conversion Factors

1 kilogram per meter = .6720 pound per foot.
1 gram per square millimeter = 1.422 pounds per square inch.
1 kilogram per square meter = 0.2048 pound per square foot.
1 kilogram per cubic meter = .0624 pound per cubic foot.
1 degree centigrade = 1.8 degree Fahrenheit.
1 pound per foot = 1.488 kilograms per meter.
1 pound per square foot = 4.882 kilograms per square meter.
1 pound per cubic foot = 16.02 kilograms per cubic meter.
1 degree Fahrenheit = .5556 degrees Centigrade.
1 Calorie French Thermal Unit) = 3.968 B. T. U. (British Thermal Unit).
1 Horse-power = { 33,000 foot-pounds per minute. / 746 Watts.
1 Watt (Unit of Electrical Power) = { .00134 Horse-power. / 44.24 foot-pounds per minute
1 Kilowatt = { 1000 Watts. / 1.34 Horse-power. / 44240 foot-pounds per minute.

EQUIVALENTS OF COMPOUND UNITS

Symbols	Metric Units	American Equivalents
gr./cm.	Gram per centimeter	0.0055 pound per inch
kg./m.	Kilogram per meter	0.055 pound per inch
kg./km.	Kilogram per kilometer	3.54 pounds per mile
kg./qcm.	Kilogram per square centimeter	14.22 pounds per square inch
kg./ha.	Kilogram per hectar	0.89 pound per acre
t./m.^{2}	Metric ton per square meter	0.102 short ton per square foot
kg./m.^{3}	Kilogram per cubic meter	0.062 pound per cubic foot
kg./hl.	Kilogram per hectoliter	0.083 pounds per gallon
t./m.^{3}	Metric ton per cubic meter	62.4 pounds per cubic foot
kg./h.-p.	Kilogram per Continental horsepower	2.23 pounds per American h.-p.
kg./t.	Kilogram per metric ton	2 pounds per short ton
kgm./kg.	Kilogram-meter per kilogram	3.28 foot-pounds per pound
kgm./qcm.	Kilogram-meter per square centimeter	46.58 foot-pounds per square inch
t./km.	Metric ton per kilometer	1.77 short tons per mile
t.-km.	Metric ton-kilometer	0.6849 short ton-mile

Decimal Equivalents of Fractions of Millimeters. (Advancing by $\frac{1}{100}$ mm.)

mm.	Inches	mm.	Inches	mm.	Inches	mm.	Inches
$\frac{1}{100}$	= .00039	$\frac{26}{100}$	= .01024	$\frac{51}{100}$	= .02008	$\frac{76}{100}$	= .02992
$\frac{2}{100}$	= .00079	$\frac{27}{100}$	= .01063	$\frac{52}{100}$	= .02047	$\frac{77}{100}$	= .03032
$\frac{3}{100}$	= .00118	$\frac{28}{100}$	= .01102	$\frac{53}{100}$	= .02087	$\frac{78}{100}$	= .03071
$\frac{4}{100}$	= .00157	$\frac{29}{100}$	= .01142	$\frac{54}{100}$	= .02126	$\frac{79}{100}$	= .03110
$\frac{5}{100}$	= .00197	$\frac{30}{100}$	= .01181	$\frac{55}{100}$	= .02165	$\frac{80}{100}$	= .03150
$\frac{6}{100}$	= .00236	$\frac{31}{100}$	= .01220	$\frac{56}{100}$	= .02205	$\frac{81}{100}$	= .03189
$\frac{7}{100}$	= .00276	$\frac{32}{100}$	= .01260	$\frac{57}{100}$	= .02244	$\frac{82}{100}$	= .03228
$\frac{8}{100}$	= .00315	$\frac{33}{100}$	= .01299	$\frac{58}{100}$	= .02283	$\frac{83}{100}$	= .03268
$\frac{9}{100}$	= .00354	$\frac{34}{100}$	= .01339	$\frac{59}{100}$	= .02323	$\frac{84}{100}$	= .03307
$\frac{10}{100}$	= .00394	$\frac{35}{100}$	= .01378	$\frac{60}{100}$	= .02362	$\frac{85}{100}$	= .03346
$\frac{11}{100}$	= .00433	$\frac{36}{100}$	= .01417	$\frac{61}{100}$	= .02402	$\frac{86}{100}$	= .03386
$\frac{12}{100}$	= .00472	$\frac{37}{100}$	= .01457	$\frac{62}{100}$	= .02441	$\frac{87}{100}$	= .03425
$\frac{13}{100}$	= .00512	$\frac{38}{100}$	= .01496	$\frac{63}{100}$	= .02480	$\frac{88}{100}$	= .03465
$\frac{14}{100}$	= .00551	$\frac{39}{100}$	= .01535	$\frac{64}{100}$	= .02520	$\frac{89}{100}$	= .03504
$\frac{15}{100}$	= .00591	$\frac{40}{100}$	= .01575	$\frac{65}{100}$	= .02559	$\frac{90}{100}$	= .03543
$\frac{16}{100}$	= .00630	$\frac{41}{100}$	= .01614	$\frac{66}{100}$	= .02598	$\frac{91}{100}$	= .03583
$\frac{17}{100}$	= .00669	$\frac{42}{100}$	= .01654	$\frac{67}{100}$	= .02638	$\frac{92}{100}$	= .03622
$\frac{18}{100}$	= .00709	$\frac{43}{100}$	= .01693	$\frac{68}{100}$	= .02677	$\frac{93}{100}$	= .03661
$\frac{19}{100}$	= .00748	$\frac{44}{100}$	= .01732	$\frac{69}{100}$	= .02717	$\frac{94}{100}$	= .03701
$\frac{20}{100}$	= .00787	$\frac{45}{100}$	= .01772	$\frac{70}{100}$	= .02756	$\frac{95}{100}$	= .03740
$\frac{21}{100}$	= .00827	$\frac{46}{100}$	= .01811	$\frac{71}{100}$	= .02795	$\frac{96}{100}$	= .03780
$\frac{22}{100}$	= .00866	$\frac{47}{100}$	= .01850	$\frac{72}{100}$	= .02835	$\frac{97}{100}$	= .03819
$\frac{23}{100}$	= .00906	$\frac{48}{100}$	= .01890	$\frac{73}{100}$	= .02874	$\frac{98}{100}$	= .03858
$\frac{24}{100}$	= .00945	$\frac{49}{100}$	= .01929	$\frac{74}{100}$	= .02913	$\frac{99}{100}$	= .03898
$\frac{25}{100}$	= .00984	$\frac{50}{100}$	= .01969	$\frac{75}{100}$	= .02953	1	= .03937

Decimal Equivalents of Millimeters and Fractions of Millimeters. (Advancing by $\frac{1}{50}$ mm. and 1 mm.)

mm.	Inches	mm.	Inches	mm.	Inches	mm.	Inches
		$\frac{40}{50}$ =	.03150	31 =	1.22047	71 =	2.79527
$\frac{1}{50}$ =	.00079	$\frac{41}{50}$ =	.03228	32 =	1.25984	72 =	2.83464
$\frac{2}{50}$ =	.00157	$\frac{42}{50}$ =	.03307	33 =	1.29921	73 =	2.87401
$\frac{3}{50}$ =	.00236	$\frac{43}{50}$ =	.03386	34 =	1.33858	74 =	2.91338
$\frac{4}{50}$ =	.00315	$\frac{44}{50}$ =	.03465	35 =	1.37795	75 =	2.95275
$\frac{5}{50}$ =	.00394	$\frac{45}{50}$ =	.03543	36 =	1.41732	76 =	2.99212
$\frac{6}{50}$ =	.00472	$\frac{46}{50}$ =	.03622	37 =	1.45669	77 =	3.03149
$\frac{7}{50}$ =	.00551	$\frac{47}{50}$ =	.03701	38 =	1.49606	78 =	3.07086
$\frac{8}{50}$ =	.00630	$\frac{48}{50}$ =	.03780	39 =	1.53543	79 =	3.11023
$\frac{9}{50}$ =	.00709	$\frac{49}{50}$ =	.03858	40 =	1.57480	80 =	3.14960
$\frac{10}{50}$ =	.00787	1 =	.03037	41 =	1.61417	81 =	3.18897
$\frac{11}{50}$ =	.00866	2 =	.07874	42 =	1.65354	82 =	3.22834
$\frac{12}{50}$ =	.00945	3 =	.11811	43 =	1.69291	83 =	3.26771
$\frac{13}{50}$ =	.01024	4 =	.15748	44 =	1.73228	84 =	3.30708
$\frac{14}{50}$ =	.01102	5 =	.19685	45 =	1.77165	85 =	3.34645
$\frac{15}{50}$ =	.01181	6 =	.23622	46 =	1.81102	86 =	3.38582
$\frac{16}{50}$ =	.01260	7 =	.27559	47 =	1.85039	87 =	3.42519
$\frac{17}{50}$ =	.01339	8 =	.31496	48 =	1.88976	88 =	3.46456
$\frac{18}{50}$ =	.01417	9 =	.35433	49 =	1.92913	89 =	3.50393
$\frac{19}{50}$ =	.01496	10 =	.39370	50 =	1.96850	90 =	3.54330
$\frac{20}{50}$ =	.01575	11 =	.43307	51 =	2.00787	91 =	3.58267
$\frac{21}{50}$ =	.01654	12 =	.47244	52 =	2.04724	92 =	3.62204
$\frac{22}{50}$ =	.01732	13 =	.51181	53 =	2.08661	93 =	3.66141
$\frac{23}{50}$ =	.01811	14 =	.55118	54 =	2.12598	94 =	3.70078
$\frac{24}{50}$ =	.01890	15 =	.59055	55 =	2.16535	95 =	3.74015
$\frac{25}{50}$ =	.01969	16 =	.62992	56 =	2.20472	96 =	3.77952
$\frac{26}{50}$ =	.02047	17 =	.66929	57 =	2.24409	97 =	3.81889
$\frac{27}{50}$ =	.02126	18 =	.70866	58 =	2.28346	98 =	3.85826
$\frac{28}{50}$ =	.02205	19 =	.74803	59 =	2.32283	99 =	3.89763
$\frac{29}{50}$ =	.02283	20 =	.78740	60 =	2.36220	100 =	3.93700
$\frac{30}{50}$ =	.02362	21 =	.82677	61 =	2.40157		
$\frac{31}{50}$ =	.02441	22 =	.86614	62 =	2.44094		
$\frac{32}{50}$ =	.02520	23 =	.90551	63 =	2.48031		
$\frac{33}{50}$ =	.02598	24 =	.94488	64 =	2.51968		
$\frac{34}{50}$ =	.02677	25 =	.98425	65 =	2.55905		
$\frac{35}{50}$ =	.02756	26 =	1.02362	66 =	2.59842		
$\frac{36}{50}$ =	.02835	27 =	1.06299	67 =	2.63779		
$\frac{37}{50}$ =	.02913	28 =	1.10236	68 =	2.67716		
$\frac{38}{50}$ =	.02992	29 =	1.14173	69 =	2.71653		
$\frac{39}{50}$ =	.03071	30 =	1.18110	70 =	2.75590		

1 mm. = 0.03937 in.
1 cm. = 0.3937 "
1 dm. = 3.937 "
1 m. = 39.37 "

Fractions, Decimals and Millimeters

This will be found useful in comparing the millimeter with both the decimal and common fractions of an inch.

FRACTIONS AND DECIMALS OF INCH WITH MILLIMETER EQUIVALENT

Fraction of Inch	Decimal of Inch	Millimeters	Fraction of Inch	Decimal of Inch	Millimeters
1/64	0.015625	0.3968	33/64	0.515625	13.0966
1/32	0.03125	0.7937	17/32	0.53125	13.4934
3/64	0.046875	1.1906	35/64	0.546875	13.8903
1/16	0.0625	1.5875	9/16	0.5625	14.2872
5/64	0.078125	1.9843	37/64	0.578125	14.6841
3/32	0.09375	2.3812	19/32	0.59375	15.0809
7/64	0.109375	2.7780	39/64	0.609375	15.4778
1/8	0.125	3.1749	5/8	0.625	15.8747
9/64	0.140625	3.5718	41/64	0.640625	16.2715
5/32	0.15625	3.9686	21/32	0.65625	16.6684
11/64	0.171875	4.3655	43/64	0.671875	17.0653
3/16	0.1875	4.7624	11/16	0.6875	17.4621
13/64	0.203125	5.1592	45/64	0.703125	17.8590
7/32	0.21875	5.5561	23/32	0.71875	18.2559
15/64	0.234375	5.9530	47/64	0.734375	18.6527
1/4	0.25	6.3498	3/4	0.75	19.0496
17/64	0.265625	6.7467	49/64	0.765625	19.4465
9/32	0.28125	7.1436	25/32	0.78125	19.8433
19/64	0.296875	7.5404	51/64	0.796875	20.2402
5/16	0.3125	7.9373	13/16	0.8125	20.6371
21/64	0.328125	8.3342	53/64	0.828125	21.0339
11/32	0.34375	8.7310	27/32	0.843750	21.4308
23/64	0.359375	9.1279	55/64	0.859375	21.8277
3/8	0.375	9.5248	7/8	0.875	22.2245
25/64	0.390625	9.9216	57/64	0.890625	22.6214
13/32	0.40625	10.3185	29/32	0.90625	23.0183
27/64	0.421875	10.7154	59/64	0.921875	23.4151
7/16	0.4375	11.1122	15/16	0.9375	23.8120
29/64	0.453125	11.5091	61/64	0.953125	24.2089
15/32	0.46875	11.9060	31/32	0.96875	24.6057
31/64	0.484375	12.3029	63/64	0.984375	25.0026
1/2	0.5	12.6997	1	1.0	25.3995

EQUIVALENTS OF ENGLISH INCHES IN MILLIMETERS (39.37 inches = 1 meter)

Inch	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	Inch
0	0.0	1.6	3.2	4.8	6.4	7.9	9.5	11.1	12.7	14.3	15.9	17.5	19.1	20.6	22.2	23.8	0
1	25.4	27.0	28.6	30.2	31.7	33.3	34.9	36.5	38.1	39.7	41.3	42.9	44.4	46.0	47.6	49.2	1
2	50.8	52.4	54.0	55.6	57.1	58.7	60.3	61.9	63.5	65.1	66.7	68.3	69.8	71.4	73.0	74.6	2
3	76.2	77.8	79.4	81.0	82.5	84.1	85.7	87.3	88.9	90.5	92.1	93.7	95.2	96.8	98.4	100.0	3
4	101.6	103.2	104.8	106.4	108.0	109.5	111.1	112.7	114.3	115.9	117.5	119.1	120.7	122.2	123.8	125.4	4
5	127.0	128.6	130.2	131.8	133.4	134.9	136.5	138.1	139.7	141.3	142.9	144.5	146.1	147.6	149.2	150.8	5
6	152.4	154.0	155.6	157.2	158.8	160.3	161.9	163.5	165.1	166.7	168.3	169.9	171.5	173.0	174.6	176.2	6
7	177.8	179.4	181.0	182.6	184.2	185.7	187.3	188.9	190.5	192.1	193.7	195.3	196.9	198.4	200.0	201.6	7
8	203.2	204.8	206.4	208.0	209.6	211.1	212.7	214.3	215.9	217.5	219.1	220.7	222.3	223.8	225.4	227.0	8
9	228.6	230.2	231.8	233.4	235.0	236.5	238.1	239.7	241.3	242.9	244.5	246.1	247.7	249.2	250.8	252.4	9
10	254.0	255.6	257.2	258.8	260.4	261.9	263.5	265.1	266.7	268.3	269.9	271.5	273.1	274.6	276.2	277.8	10
11	279.4	281.0	282.6	284.2	285.7	287.3	288.9	290.5	292.1	293.7	295.3	296.9	298.4	300.0	301.6	303.2	11
12	304.8	306.4	308.0	309.6	311.1	312.7	314.3	315.9	317.5	319.1	320.7	322.3	323.8	325.4	327.0	328.6	12
13	330.2	331.8	333.4	335.0	336.5	338.1	339.7	341.3	342.9	344.5	346.1	347.7	349.2	350.8	352.4	354.0	13
14	355.6	357.2	358.8	360.4	361.9	363.5	365.1	366.7	368.3	369.9	371.5	373.1	374.6	376.2	377.8	379.4	14
15	381.0	382.6	384.2	385.8	387.3	388.9	390.5	392.1	393.7	395.3	396.9	398.5	400.0	401.6	403.2	404.8	15
16	406.4	408.0	409.6	411.2	412.7	414.3	415.9	417.5	419.1	420.7	422.3	423.9	425.4	427.0	428.6	430.2	16
17	431.8	433.4	435.0	436.6	438.1	439.7	441.3	442.9	444.5	446.1	447.7	449.3	450.8	452.4	454.0	455.6	17
18	457.2	458.8	460.4	462.0	463.5	465.1	466.7	468.3	469.9	471.5	473.1	474.7	476.2	477.8	479.4	481.0	18
19	482.6	484.2	485.8	487.4	488.9	490.5	492.1	493.7	495.3	496.9	498.5	500.1	501.6	503.2	504.8	506.4	19
20	508.0	509.6	511.2	512.8	514.3	515.9	517.5	519.1	520.7	522.3	523.9	525.5	527.0	528.6	530.2	531.8	20
21	533.4	535.0	536.6	538.2	539.7	541.3	542.9	544.5	546.1	547.7	549.3	550.9	552.4	554.0	555.6	557.2	21
22	558.8	560.4	562.0	563.6	565.1	566.7	568.3	569.9	571.5	573.1	574.7	576.3	577.8	579.4	581.0	582.6	22
23	584.2	585.8	587.4	589.0	590.5	592.1	593.7	595.3	596.9	598.5	600.1	601.7	603.2	604.8	606.4	608.0	23

Comparison of Standard Linear Units—Approximate Values

A	One Milli.	One Centi.	One Inch	One Decim.	One Foot	One Yard	One Meter	One Rod	One Chain	One Hektom.	One Furlong	One Kilo.	One Mile	One Knot	A
Milli.	Equals 1	Equals 10	Equals 25.4	Equals 100	Equals 304.80	Equals 914.40	Equals 1000	Equals 5029.2	Equals 20116.8	Equals 100,000	Equals 201,168	Equals 1,000,000	Equals 1,609,347	Equals 1,855,037	Milli.
Centi.	1/10 .1	1	2.54	10	30.48	91.44	100	502.9	2011.68	10,000	20116.8	100,000	160,934	185,325	Centi.
Inches	1/25 0.03937	5/10 0.3937	1	3.937	12	36	39.37	198	792	3937.	7920	39,370	63,360	73,033	Inches
Decim.	1/100 0.01	1/10 0.1	0.254	1	3.048	9.144	10	50.29	201.16	1000	2011.7	10,000	16,093	18,532	Decim.
Feet	0.00328	1/30 0.0328	1/12 0.0833 1/3	1/8 + 0.32808	1	3	3.2808 3'-3 3/8"	16.5	66	328.08	660	3280.8	5280	6080.2	Feet
Yards	0.00109	0.01093	1/36 0.0278	1/9 0.10936	1/3 0.333 1/3	1	1.0936	5.5	22	100.36	220	1093.6	1760	2026.7	Yards
Meters	1/1000 0.001	1/100 0.01	1/40 0.02540	1/10 0.1	3/10 0.30480	9/10 0.91440	1	5.0292	20.116	100	201.17	1000	1609.3	1853.2	Meters
Rods	0.00019	0.00198	1/198 0.00505	0.01988	2/33 0.06060	2/11 0.18181	0.19883	1	4	19.883	40	198.83	320	368.95	Rods
Chains	1/20000 .00005+	1/2000 0.00049	1/792 0.00126	0.00497	1/69 0.01515	1/22 0.04545	0.04970	1/4 0.25	1	4.9708	10	49.708	80	92.23	Chains
Hektom.	1/100000	1/10000	1/3937 0.000251	1/1000	0.00305	0.00914	1/100	0.05029	0.20117	1	2.0117	10	16.093	18.53+	Hectom.
Furlongs	1/200000	1/20000	1/7920 .00012+	1/2000	1/660 0.00151	1/220 0.00454	0.00497	1/40 0.025	1/10	0.49078	1	4.9708	8	9.223	Furlongs
Kilo.		1/100000	1/39370 0.000025	1/10000	0.00030	0.00091	1/1000	0.00503	0.020117	1/10	0.20117	1	1.6093+	1.853+	Kilo.
Miles			1/63360		1/5280	1/1760 0.00056	0.00062	1/320 0.00312	1/80 0.0125	0.06213	1/8 0.125	5/8 0.62137	1	1.151+	Miles
Knots (U. S.)			1/73033		0.00016	0.00049	0.00054	0.00271	0.01084	0.05396	0.10844	0.5396+	App. 7/8 0.8684+	1	Knots (U. S.)

NOTE: At the point where any vertical column crosses any horizontal column will be found the value of the **UNIT** named at the head of the vertical column expressed in terms of the **UNIT** named under A opposite the horizontal column. Thus, under 1 meter find 1.0936 yards; under 1 foot find 0.3048 meter.

Decimal Equivalents of Fractions below $\frac{1}{2}''$

Decimal Equivalents	Fractional Parts of an Inch										Decimal Equivalents
	6	7	8	12	14	16	24	28	32	64	
.015625										1	.015625
.03125									1	2	.03125
.035714								1			.035714
.041667							1				.041667
.046875										3	.046875
.0625						1			2	4	.0625
.071429					1			2			.071429
.078125										5	.078125
.083333				1			2				.083333
.09375									3	6	.09375
.107143								3			.107143
.109375										7	.109375
.125			1			2	3		4	8	.125
.140625										9	.140625
.142857		1			2			4			.142857
.15625									5	10	.15625
.166666	1			2			4				.166666
.171875										11	.171875
.178571								5			.178571
.1875						3			6	12	.1875
.203125										13	.203125
.208333							5				.208333
.214286					3			6			.214286
.21875									7	14	.21875
.234375										15	.234375
.25			2	3		4	6	7	8	16	.25
.265625										17	.265625
.28125								8	9	18	.28125
.285714		2			4						.285714
.291666							7				.291666
.296875										19	.296875
.3125						5			10	20	.3125
.321429								9			.321429
.328125										21	.328125
.333333	2			4			8				.333333
.34375									11	22	.34375
.357143					5			10			.357143
.359375										23	.359375
.375			3			6	9		12	24	.375
.390625										25	.390625
.392857								11			.392857
.40625									13	26	.40625
.41666				5			10				.41666
.421875										27	.421875
.428571		3			6			12			.428571
.4375						7			14	28	.4375
.453125										29	.453125
.458333							11				.458333
.464286								13			.464286
.46875									15	30	.46875
.484375										31	.484375
.5	3		4	6	7	8	12	14	16	32	.5

Decimal Equivalents of Fractions between $\frac{1}{2}''$ and $1''$

Decimal Equivalents	Fractional Parts of an Inch										Decimal Equivalents
	6	7	8	12	14	16	24	28	32	64	
.515625										33	.515625
.53125									17	34	.53125
.535714								15			.535714
.541666							13				.541666
.546875										35	.546875
.5625						9			18	36	.5625
.571429		4			8			16			.571429
.578125										37	.578125
.583333				7			14				.583333
.59375									19	38	.59375
.607143								17			.607143
.609375										39	.609375
.625			5			10	15		20	40	.625
.640625										41	.640625
.642867					9			18			.642867
.65625									21	42	.65625
.666666	4			8			16				.666666
.671875										43	.671875
.678571								19			.678571
.6875						11			22	44	.6875
.703125										45	.703125
.708333							17				.708333
.714286		5			10			20			.714286
.71875									23	46	.71875
.734375										47	.734375
.75			6	9		12	18	21	24	48	.75
.765625										49	.765625
.78125									25	50	.78125
.785714					11			22			.785714
.791666							19				.791666
.796875										51	.796875
.8125						13			26	52	.8125
.821429								23			.821429
.828125										53	.828125
.833333	5			10			20				.833333
.84375									27	54	.84375
.857143		6			12			24			.857143
.859375										55	.859375
.875			7			14	21		28	56	.875
.890625										57	.890625
.892857								25			.892857
.90625									29	58	.90625
.916666				11			22				.916666
.921875										59	.921875
.928571					13			26			.928571
.9375						15			30	60	.9375
.953125										61	.953125
.958333							23				.958333
.964286								27			.964286
.96875									31	62	.96875
.984375										63	.984375

WATER CONVERSION FACTORS

U. S. gallons	×	8.33	= pounds.
U. S. gallons	×	0.13368	= cubic feet.
U. S. gallons	×	231	= cubic inches.
U. S. gallons	×	0.83	= English gallons
U. S. gallons	×	3.78	= liters.
English gallons (Imperial)	×	10	= pounds.
English gallons (Imperial)	×	0.16	= cubic feet.
English gallons (Imperial)	×	277.274	= cubic inches.
English gallons (Imperial)	×	1.2	= U. S. gallons.
English gallons (Imperial)	×	4.537	= liters.
Cubic inches of water (39.1°)	×	0.036125	= pounds.
Cubic inches of water (39.1°)	×	0.004329	= U. S. gallons.
Cubic inches of water (39.1°)	×	0.003607	= English gallons.
Cubic inches of water (39.1°)	×	0.576384	= ounces.
Cubic feet (of water) (39.1°)	×	62.425	= pounds.
Cubic feet (of water) (39.1°)	×	7.48	= U. S. gallons.
Cubic feet (of water) (39.1°)	×	6.232	= English gallons.
Cubic feet (of water) (39.1°)	×	0.028	= tons.
Pounds of water	×	27.72	= cubic inches.
Pounds of water	×	0.01602	= cubic feet.
Pounds of water	×	0.12	= U. S. gallons.
Pounds of water	×	0.10	= English gallons.

CONVENIENT MULTIPLIERS

Inches	×	0.08333	= feet.	Sq. inches	×	0.00695	= Sq. feet.
Inches	×	0.02778	= yards.	Sq. inches	×	0.0007716	= Sq. yards.
Inches	×	0.00001578	= miles.	Cu. inches	×	0.00058	= Cu. feet.
				Cu. inches	×	0.0000214	= Cu. yards
Feet	×	0.3334	= yards.	Sq. feet	×	144	= Sq. inches.
Feet	×	0.00019	= miles.	Sq. feet	×	0.1112	= Sq. yards.
Yards	×	36	= inches.	Cu. feet	×	1728	= Cu. inches.
Yards	×	3	= feet.	Cu. feet	×	0.03704	= Cu. yards.
Yards	×	0.0005681	= miles.	Sq. yards	×	1296	= Sq. inches.
Miles	×	63360	= inches.	Sq. yards	×	9	= Sq. feet.
Miles	×	5280	= feet.	Cu. yards	×	46656	= Cu. inches.
Miles	×	1760	= yards.	Cu. yards	×	27	= Cu. feet.
Avoir. oz.	×	0.0625	= pounds.	Avoir. lbs.	×	0.0005	= tons.
Avoir. oz.	×	0.00003125	= tons.	Avoir. tons	×	32000	= ounces.
Avoir. lbs.	×	16	= ounces.	Avoir. tons	×	2000	= pounds.

TABLE OF PRIME-NUMBER FRACTIONS

THE table shows decimal equivalents of common fractions having prime numbers for both numerator and denominator. As an example, suppose it is required to find the thread angle of a worm.

$$\textit{Tangent thread angle} = \frac{\textit{Number threads}}{\textit{Diametral pitch} \times \textit{pitch diameter}}.$$

Find the angle of a worm 7 diametral pitch, 5 threads, 2-inch P. diameter:

$$\textit{Tangent angle} = \tfrac{5}{7} \times \tfrac{1}{2}$$

Then from table

$$\tfrac{5}{7} = 0.7143 \text{ and } \frac{0.7143}{2} = 0.35715$$

which is the tangent for 19 degrees 21 minutes, nearly.

PRIME NUMBER FRACTIONS AND THEIR DECIMAL EQUIVALENTS

Denominators (Prime Numbers Only)

Numerators (Prime Numbers only)	97	89	83	79	73	71	67	61	59	53	47	43
1	.0103	.0112	.0120	.0126	.0137	.0141	.0149	.0164	.0169	.0189	.0213	.0233
3	.0309	.0337	.0361	.0380	.0411	.0423	.0448	.0492	.0508	.0566	.0638	.0698
5	.0515	.0562	.0602	.0633	.0685	.0704	.0746	.0820	.0847	.0943	.1064	.1163
7	.0722	.0787	.0843	.0886	.0959	.0986	.1045	.1148	.1186	.1321	.1489	.1628
11	.1134	.1236	.1325	.1392	.1507	.1549	.1642	.1803	.1864	.2075	.2340	.2558
13	.1340	.1461	.1566	.1646	.1781	.1831	.1940	.2131	.2203	.2453	.2766	.3023
17	.1753	.1910	.2048	.2152	.2329	.2394	.2537	.2787	.2881	.3208	.3617	.3953
19	.1959	.2135	.2289	.2405	.2603	.2676	.2836	.3115	.3220	.3585	.4043	.4419
23	.2371	.2584	.2771	.2911	.3151	.3239	.3433	.3770	.3898	.4340	.4894	.5349
29	.2990	.3258	.3494	.3671	.3973	.4085	.4328	.4754	.4915	.5472	.6170	.6744
31	.3196	.3483	.3735	.3924	.4247	.4366	.4627	.5082	.5254	.5849	.6596	.7209
37	.3814	.4157	.4458	.4684	.5068	.5211	.5522	.6066	.6271	.6981	.7872	.8605
41	.4227	.4607	.4940	.5190	.5616	.5775	.6119	.6721	.6949	.7736	.8723	.9535
43	.4433	.4831	.5181	.5443	.5890	.6056	.6418	.7049	.7288	.8113	.9149	
47	.4845	.5281	.5663	.5949	.6438	.6620	.7015	.7705	.7966	.8868		
53	.5464	.5955	.6380	.6709	.7260	.7465	.7910	.8689	.8983			
59	.6082	.6629	.7108	.7468	.8082	.8310	.8806	.9672				
61	.6289	.6854	.7349	.7722	.8356	.8592	.9104					
67	.6907	.7528	.8072	.8481	.9178	.9437						
71	.7320	.7978	.8554	.8987	.9726							
73	.7526	.8202	.8795	.9241								
79	.8144	.8876	.9518									
83	.8557	.9326										
89	.9175											

Denominators (Prime Numbers Only)

Numerators (Prime Numbers only)	41	37	31	29	23	19	17	13	11	7	5	3
1	.0244	.0270	.0323	.0345	.0435	.0526	.0588	.0769	.0909	.1429	.2000	.3333
3	.0732	.0811	.0968	.1034	.1304	.1579	.1765	.2308	.2727	.4286	.6000	
5	.1220	.1351	.1613	.1724	.2174	.2632	.2941	.3846	.4545	.7143		
7	.1707	.1892	.2258	.2414	.3043	.3684	.4118	.5385	.6364			
11	.2683	.2973	.3458	.3793	.4783	.5789	.6471	.8462				
13	.3171	.3514	.4194	.4483	.5652	.6842	.7647					
17	.4146	.4595	.5484	.5862	.7391	.8947						
19	.4634	.5135	.6129	.6552	.8261							
23	.5610	.6212	.7419	.7931								
29	.7073	.7838	.9355									
31	.7561	.8778										
37	.9024											

Only those common fractions having prime numbers for both the numerator and denominator are given in table. Others can be found by simple multiplication or division.

Decimal Equivalents of Fractions and Nearest Equivalent 64ths

Fr.	Decimal	Nearest 64th	Fr.	Decimal	Nearest 64th	Fr.	Decimal	Nearest 64th
1/32	0.0313		2/15	0.1333	1/8	7/27	0.2593	
1/31	0.0323		8/25	0.1364		9/35	0.2609	
1/30	0.0333		4/29	0.1379		5/19	0.2632	
1/29	0.0345	1/32	1/7	0.1429	9/64	1/5	0.2667	17/64
1/28	0.0357		4/27	0.1481		8/35	0.2692	
1/27	0.0370		3/20	0.1500		3/11	0.2727	
1/26	0.0385		2/13	0.1538		8/29	0.2759	
1/25	0.0400		3/22	0.1563	5/32	5/18	0.2778	
1/24	0.0417		1/9	0.1579		2/5	0.2800	
1/23	0.0435		4/25	0.1600		9/32	0.2813	9/32
1/22	0.0455		5/31	0.1613		4/7	0.2857	
1/21	0.0476	3/64	1/6	0.1667		9/31	0.2903	
1/20	0.0500		5/29	0.1724	11/64	7/24	0.2917	
1/19	0.0526		4/23	0.1739		5/17	0.2941	
1/18	0.0556		3/17	0.1765		8/27	0.2963	19/64
1/17	0.0589	1/16	5/28	0.1785		3/10	0.3000	
1/16	0.0625		2/11	0.1818		7/23	0.3043	
2/31	0.0645		7/27	0.1852		4/13	0.3077	
1/15	0.0667		3/16	0.1875	3/16	9/29	0.3103	
2/29	0.0690		4/21	0.1905		5/16	0.3125	5/16
1/14	0.0714		5/26	0.1923		6/19	0.3158	
2/27	0.0740		6/31	0.1935		7/22	0.3182	
1/13	0.0769	5/64	1/5	0.2000	13/64	8/25	0.3200	
2/25	0.0800		6/29	0.2069		9/28	0.3214	
1/12	0.0833		5/24	0.2083		10/31	0.3226	21/64
2/23	0.0870		4/19	0.2105		1/3	0.3333	
1/11	0.0909		7/33	0.2143		11/32	0.3438	11/32
3/32	0.0938	5/32	5/23	0.2174		10/29	0.3448	
2/21	0.0952		7/32	0.2188	7/32	9/26	0.3462	
3/31	0.0968		2/9	0.2222		8/23	0.3478	
1/10	0.1000		7/31	0.2258		7/20	0.3500	
3/29	0.1034		5/22	0.2273		17/48	0.3529	
1/9	0.1053		3/13	0.2308		11/31	0.3548	
3/28	0.1071		7/30	0.2333	15/64	5/14	0.3571	
1/8	0.1111	7/64	4/17	0.2353		9/25	0.3600	23/64
2/25	0.1154		2/11	0.2381		4/11	0.3636	
1/7	0.1176		6/25	0.2400		11/30	0.3667	
2/25	0.1200	1/8	7/29	0.2414		7/19	0.3684	
4/31	0.1250		1/4	0.2500	1/4	10/27	0.3704	
3/28	0.1290		8/31	0.2580		3/8	0.3750	3/8
	0.1304							

Decimal Equivalents of Fractions and Nearest Equivalent 64ths

Fr.	Decimal	Nearest 64th	Fr.	Decimal	Nearest 64th	Fr.	Decimal	Nearest 64th
$\frac{1}{32}$	0.3793	$\frac{3}{8}$	$\frac{16}{31}$	0.5161	$\frac{33}{64}$	$\frac{11}{21}$	0.6296	$\frac{5}{8}$
$\frac{6}{21}$	0.3810		$\frac{25}{49}$	0.5172		$\frac{12}{23}$	0.6316	
$\frac{5}{13}$	0.3846		$\frac{17}{33}$	0.5185		$\frac{19}{36}$	0.6333	
$\frac{12}{31}$	0.3871		$\frac{26}{51}$	0.5200		$\frac{7}{13}$	0.6364	
$\frac{7}{18}$	0.3889		$\frac{9}{17}$	0.5217		$\frac{11}{20}$	0.6400	$\frac{41}{64}$
$\frac{25}{64}$	0.3913	$\frac{25}{64}$	$\frac{11}{21}$	0.5238		$\frac{19}{35}$	0.6429	
$\frac{12}{31}$	0.3929		$\frac{10}{19}$	0.5263		$\frac{14}{25}$	0.6452	
$\frac{2}{5}$	0.4000		$\frac{19}{36}$	0.5294		$\frac{20}{31}$	0.6471	
$\frac{13}{32}$	0.4063	$\frac{13}{32}$	$\frac{7}{13}$	0.5313	$\frac{17}{32}$	$\frac{11}{17}$	0.6500	
$\frac{1}{2\frac{1}{2}}$	0.4074		$\frac{8}{15}$	0.5333		$\frac{13}{20}$	0.6522	
$\frac{9}{22}$	0.4091		$\frac{15}{28}$	0.5357		$\frac{15}{23}$	0.6538	
$\frac{7}{17}$	0.4118		$\frac{13}{24}$	0.5385		$\frac{17}{26}$	0.6552	
$\frac{12}{29}$	0.4138		$\frac{11}{20}$	0.5417		$\frac{19}{29}$	0.6563	$\frac{21}{32}$
$\frac{5}{12}$	0.4167		$\frac{11}{17}$	0.5455	$\frac{35}{64}$	$\frac{21}{32}$	0.6667	$\frac{43}{64}$
$\frac{13}{31}$	0.4194		$\frac{6}{11}$	0.5484		$\frac{23}{35}$	0.6774	
$\frac{9}{21}$	0.4211	$\frac{27}{64}$	$\frac{17}{31}$	0.5500		$\frac{12}{19}$	0.6786	
$\frac{11}{26}$	0.4231		$\frac{20}{36}$	0.5517		$\frac{25}{38}$	0.6800	
$\frac{3}{7}$	0.4286		$\frac{29}{52}$	0.5556		$\frac{17}{25}$	0.6818	
$\frac{13}{30}$	0.4333		$\frac{5}{9}$	0.5600		$\frac{28}{41}$	0.6842	
$\frac{10}{23}$	0.4348		$\frac{14}{25}$	0.5625	$\frac{9}{16}$	$\frac{11}{16}$	0.6875	$\frac{11}{16}$
$\frac{7}{16}$	0.4375	$\frac{7}{16}$	$\frac{19}{34}$	0.5652		$\frac{20}{29}$	0.6897	
$\frac{11}{25}$	0.4400		$\frac{17}{30}$	0.5667		$\frac{9}{13}$	0.6923	
$\frac{4}{9}$	0.4444		$\frac{4}{7}$	0.5714		$\frac{16}{23}$	0.6957	
$\frac{13}{29}$	0.4483		$\frac{15}{26}$	0.5769		$\frac{7}{10}$	0.7000	
$\frac{9}{20}$	0.4500		$\frac{11}{19}$	0.5789	$\frac{37}{64}$	$\frac{19}{27}$	0.7037	$\frac{45}{64}$
$\frac{14}{31}$	0.4516	$\frac{29}{64}$	$\frac{18}{31}$	0.5806		$\frac{27}{38}$	0.7059	
$\frac{5}{11}$	0.4545		$\frac{7}{12}$	0.5833		$\frac{17}{24}$	0.7083	
$\frac{11}{24}$	0.4583		$\frac{17}{29}$	0.5862		$\frac{24}{34}$	0.7097	
$\frac{6}{13}$	0.4615		$\frac{10}{17}$	0.5882		$\frac{5}{7}$	0.7143	
$\frac{13}{28}$	0.4642		$\frac{19}{32}$	0.5909		$\frac{33}{32}$	0.7188	$\frac{23}{32}$
$\frac{7}{15}$	0.4667		$\frac{16}{27}$	0.5926		$\frac{18}{25}$	0.7200	
$\frac{15}{32}$	0.4688	$\frac{15}{32}$	$\frac{19}{32}$	0.5938	$\frac{19}{32}$	$\frac{13}{18}$	0.7222	
$\frac{8}{17}$	0.4706		$\frac{3}{5}$	0.6000		$\frac{21}{29}$	0.7241	
$\frac{9}{19}$	0.4737		$\frac{17}{28}$	0.6071		$\frac{8}{11}$	0.7273	
$\frac{10}{21}$	0.4762		$\frac{14}{23}$	0.6087	$\frac{39}{64}$	$\frac{19}{26}$	0.7308	
$\frac{23}{48}$	0.4783		$\frac{11}{18}$	0.6111		$\frac{17}{23}$	0.7333	$\frac{47}{64}$
$\frac{12}{25}$	0.4800		$\frac{19}{31}$	0.6129		$\frac{17}{24}$	0.7368	
$\frac{13}{27}$	0.4815		$\frac{8}{13}$	0.6154		$\frac{19}{27}$	0.7391	
$\frac{23}{48}$	0.4828	$\frac{31}{64}$	$\frac{13}{21}$	0.6190		$\frac{20}{27}$	0.7407	
$\frac{15}{31}$	0.4839		$\frac{23}{37}$	0.6207		$\frac{23}{31}$	0.7419	
$\frac{1}{2}$	0.5000	$\frac{1}{2}$	$\frac{5}{8}$	0.6250	$\frac{5}{8}$	$\frac{3}{4}$	0.7500	$\frac{3}{4}$

Decimal Equivalents of Fractions and Nearest Equivalent 64ths

Fr.	Decimal	Nearest 64th	Fr.	Decimal	Nearest 64th	Fr.	Decimal	Nearest 64th
22/29	0.7586		26/31	0.8387		11/12	0.9167	
23/30	0.7600		27/32	0.8400		23/25	0.9200	
24/31	0.7619		16/19	0.8421		11/12	0.9231	59/64
13/17	0.7647	49/64	17/20	0.8438	27/32	24/26	0.9259	
25/32	0.7667		11/13	0.8462		25/27	0.9286	
10/13	0.7692		18/21	0.8500		13/14	0.9310	
17/22	0.7727		19/22	0.8519		14/15	0.9333	
24/31	0.7742		6/7	0.8571	55/64	29/31	0.9355	
7/9	0.7778		25/29	0.8621		15/16	0.9375	15/16
25/32	0.7813	25/32	19/22	0.8636		16/17	0.9412	
18/23	0.7826		13/15	0.8667		17/18	0.9444	
11/14	0.7857		20/23	0.8696		18/19	0.9474	
15/19	0.7895		27/31	0.8710		19/20	0.9500	
22/28	0.7917		7/8	0.8750	7/8	20/21	0.9524	61/64
23/29	0.7931	51/64	22/25	0.8800		21/22	0.9545	
4/5	0.8000		15/17	0.8824		22/23	0.9565	
25/31	0.8065		23/26	0.8846		23/24	0.9583	
21/26	0.8077		8/9	0.8889		24/25	0.9600	
21/26	0.8095		25/28	0.8929	57/64	25/26	0.9615	
13/16	0.8125	13/16	17/19	0.8947		26/27	0.9630	
27/33	0.8148		26/29	0.8966		27/28	0.9643	
9/11	0.8182		9/10	0.9000		28/29	0.9655	
23/28	0.8214		28/31	0.9032		29/30	0.9667	
29/35	0.8235		19/21	0.9048		30/31	0.9678	
17/21	0.8261		29/32	0.9063	29/32	31/32	0.9688	31/32
27/33	0.8276	53/64	10/11	0.9091		32/32	1.0000	
24/29	0.8334		21/23	0.9130				

Equivalents of Inches and Fractions of Inches in Decimals of a Foot

In.	0 In.	1 In.	2 In.	3 In.	4 In.	5 In.
		.0833	.1667	.2500	.3333	.4167
1/32	.0026	.0859	.1693	.2526	.3359	.4193
1/16	.0052	.0885	.1719	.2552	.3385	.4219
3/32	.0078	.0911	.1745	.2578	.3411	.4245
1/8	.0104	.0938	.1771	.2604	.3438	.4271
5/32	.0130	.0964	.1797	.2630	.3464	.4297
3/16	.0156	.0990	.1823	.2656	.3490	.4323
7/32	.0182	.1016	.1849	.2682	.3516	.4349
1/4	.0208	.1042	.1875	.2708	.3542	.4375
9/32	.0234	.1068	.1901	.2734	.3568	.4401
5/16	.0260	.1094	.1927	.2760	.3594	.4427
11/32	.0286	.1120	.1953	.2786	.3620	.4453
3/8	.0313	.1146	.1979	.2813	.3646	.4479
13/32	.0339	.1172	.2005	.2839	.3672	.4505
7/16	.0365	.1198	.2031	.2865	.3698	.4531
15/32	.0391	.1224	.2057	.2891	.3724	.4557
1/2	.0417	.1253	.2083	.2917	.3750	.4583
17/32	.0443	.1276	.2091	.2943	.3776	.4609
9/16	.0469	.1302	.2135	.2969	.3802	.4635
19/32	.0495	.1328	.2161	.2995	.3828	.4661
5/8	.0521	.1354	.2188	.3021	.3854	.4688
21/32	.0547	.1380	.2214	.3047	.3880	.4714
11/16	.0573	.1406	.2240	.3073	.3906	.4740
23/32	.0599	.1432	.2266	.3099	.3932	.4766
3/4	.0625	.1458	.2292	.3125	.3958	.4792
25/32	.0651	.1484	.2318	.3151	.3984	.4818
13/16	.0677	.1510	.2344	.3177	.4010	.4844
27/32	.0703	.1536	.2370	.3203	.4036	.4870
7/8	.0729	.1563	.2396	.3229	.4063	.4896
29/32	.0755	.1589	.2422	.3255	.4089	.4922
15/16	.0781	.1615	.2448	.3281	.4115	.4948
31/32	.0807	.1641	.2474	.3307	.4141	.4974

Equivalents of Inches and Fractions of Inches in Decimals of a Foot

In.	6 In.	7 In.	8 In.	9 In.	10 In.	11 In.
	.5000	.5833	.6667	.7500	.8333	.9167
1/32	.5026	.5859	.6693	.7526	.8359	.9193
1/16	.5052	.5885	.6719	.7552	.8385	.9219
3/32	.5078	.5911	.6745	.7578	.8411	.9245
1/8	.5104	.5938	.6771	.7604	.8438	.9271
5/32	.5130	.5964	.6797	.7630	.8464	.9297
3/16	.5156	.5990	.6823	.7656	.8490	.9323
7/32	.5182	.6016	.6849	.7682	.8516	.9349
1/4	.5208	.6042	.6875	.7708	.8542	.9375
9/32	.5234	.6068	.6901	.7734	.8568	.9401
5/16	.5260	.6094	.6927	.7760	.8594	.9427
11/32	.5286	.6120	.6953	.7786	.8620	.9453
3/8	.5313	.6146	.6979	.7813	.8646	.9479
13/32	.5339	.6172	.7005	.7839	.8672	.9505
7/16	.5365	.6198	.7031	.7865	.8698	.9531
15/32	.5391	.6224	.7057	.7891	.8724	.9557
1/2	.5417	.6250	.7083	.7917	.8750	.9583
17/32	.5443	.6276	.7109	.7943	.8776	.9609
9/16	.5469	.6302	.7135	.7969	.8802	.9635
19/32	.5495	.6328	.7161	.7995	.8828	.9661
5/8	.5521	.6354	.7188	.8021	.8854	.9688
21/32	.5547	.6380	.7214	.8047	.8880	.9714
11/16	.5573	.6406	.7240	.8073	.8906	.9740
23/32	.5599	.6432	.7266	.8099	.8932	.9766
3/4	.5625	.6458	.7292	.8125	.8958	.9792
25/32	.5651	.6484	.7318	.8151	.8984	.9818
13/16	.5677	.6510	.7344	.8177	.9010	.9844
27/32	.5703	.6536	.7370	.8203	.9036	.9870
7/8	.5729	.6563	.7396	.8229	.9063	.9896
29/32	.5755	.6589	.7422	.8255	.9089	.9922
15/16	.5781	.6615	.7448	.8281	.9115	.9948
31/32	.5807	.6641	.7474	.8307	.9141	.9974

DECIMAL EQUIVALENTS OF FRACTIONS OF AN INCH. (ADVANCING BY 8THS, 16THS, 32NDS AND 64THS.)

8ths, and 16ths	32nds	64ths	64ths
$\frac{1}{8}$ = .125	$\frac{1}{32}$ = .03125	$\frac{1}{64}$ = .015625	$\frac{33}{64}$ = .515625
$\frac{2}{8}$ = .250	$\frac{3}{32}$ = .09375	$\frac{3}{64}$ = .046875	$\frac{35}{64}$ = .546875
$\frac{3}{8}$ = .375	$\frac{5}{32}$ = .15625	$\frac{5}{64}$ = .078125	$\frac{37}{64}$ = .578125
$\frac{4}{8}$ = .500	$\frac{7}{32}$ = .21875	$\frac{7}{64}$ = .109375	$\frac{39}{64}$ = .609375
$\frac{5}{8}$ = .625	$\frac{9}{32}$ = .28125	$\frac{9}{64}$ = .140625	$\frac{41}{64}$ = .640625
$\frac{6}{8}$ = .750	$\frac{11}{32}$ = .34375	$\frac{11}{64}$ = .171875	$\frac{43}{64}$ = .671875
$\frac{7}{8}$ = .875	$\frac{13}{32}$ = .40625	$\frac{13}{64}$ = .203125	$\frac{45}{64}$ = .703125
16ths.	$\frac{15}{32}$ = .46875	$\frac{15}{64}$ = .234375	$\frac{47}{64}$ = .734375
$\frac{1}{16}$ = .0625	$\frac{17}{32}$ = .53125	$\frac{17}{64}$ = .265625	$\frac{49}{64}$ = .765625
$\frac{3}{16}$ = .1875	$\frac{19}{32}$ = .59375	$\frac{19}{64}$ = .296875	$\frac{51}{64}$ = .796875
$\frac{5}{16}$ = .3125	$\frac{21}{32}$ = .65625	$\frac{21}{64}$ = .328125	$\frac{53}{64}$ = .828125
$\frac{7}{16}$ = .4375	$\frac{23}{32}$ = .71875	$\frac{23}{64}$ = .359375	$\frac{55}{64}$ = .859375
$\frac{9}{16}$ = .5625	$\frac{25}{32}$ = .78125	$\frac{25}{64}$ = .390625	$\frac{57}{64}$ = .890625
$\frac{11}{16}$ = .6875	$\frac{27}{32}$ = .84375	$\frac{27}{64}$ = .421875	$\frac{59}{64}$ = .921875
$\frac{13}{16}$ = .8125	$\frac{29}{32}$ = .90625	$\frac{29}{64}$ = .453125	$\frac{61}{64}$ = .953125
$\frac{15}{16}$ = .9375	$\frac{31}{32}$ = .96875	$\frac{31}{64}$ = .484375	$\frac{63}{64}$ = .984375

DECIMAL EQUIVALENTS OF FRACTIONS OF AN INCH. (ADVANCING BY 64THS.)

$\frac{1}{64}$ = .015625	$\frac{17}{64}$ = .265625	$\frac{33}{64}$ = .515625	$\frac{49}{64}$ = .765625
$\frac{2}{32}$ = .03125	$\frac{9}{32}$ = .28125	$\frac{17}{32}$ = .53125	$\frac{25}{32}$ = .78125
$\frac{3}{64}$ = .046875	$\frac{19}{64}$ = .296875	$\frac{35}{64}$ = .546875	$\frac{51}{64}$ = .796875
$\frac{1}{16}$ = .0625	$\frac{5}{16}$ = .3125	$\frac{9}{16}$ = .5625	$\frac{13}{16}$ = .8125
$\frac{5}{64}$ = .078125	$\frac{21}{64}$ = .328125	$\frac{37}{64}$ = .578125	$\frac{53}{64}$ = .828125
$\frac{2}{32}$ = .09375	$\frac{11}{32}$ = .34375	$\frac{19}{32}$ = .59375	$\frac{27}{32}$ = .84375
$\frac{7}{64}$ = .109375	$\frac{23}{64}$ = .359375	$\frac{39}{64}$ = .609375	$\frac{55}{64}$ = .859375
$\frac{1}{8}$ = .125	$\frac{3}{8}$ = .375	$\frac{5}{8}$ = .625	$\frac{7}{8}$ = .875
$\frac{9}{64}$ = .140625	$\frac{25}{64}$ = .390625	$\frac{41}{64}$ = .640625	$\frac{57}{64}$ = .890625
$\frac{5}{32}$ = .15625	$\frac{13}{32}$ = .40625	$\frac{21}{32}$ = .65625	$\frac{29}{32}$ = .90625
$\frac{11}{64}$ = .171875	$\frac{27}{64}$ = .421875	$\frac{43}{64}$ = .671875	$\frac{59}{64}$ = .921875
$\frac{3}{16}$ = .1875	$\frac{7}{16}$ = .4375	$\frac{11}{16}$ = .6875	$\frac{15}{16}$ = .9375
$\frac{13}{64}$ = .203125	$\frac{29}{64}$ = .453125	$\frac{45}{64}$ = .703125	$\frac{61}{64}$ = .953125
$\frac{7}{32}$ = .21875	$\frac{15}{32}$ = .46875	$\frac{23}{32}$ = .71875	$\frac{31}{32}$ = .96875
$\frac{15}{64}$ = .234375	$\frac{31}{64}$ = .484375	$\frac{47}{64}$ = .734375	$\frac{63}{64}$ = .984375
$\frac{1}{4}$ = .25	$\frac{1}{2}$ = .50	$\frac{3}{4}$ = .75	

TABLE I.—SQUARE OF NUMBERS FROM "0" TO "$\frac{63}{64}$" BY 64THS—NUMBER

Added Fractions to Sixty-fourths	0	1	2	3	4	5	6	7
0	.000000	1.00000	4.00000	9.00000	16.00000	25.00000	36.00000	49.00000
$\frac{1}{64}$	.000244	1.03149	4.06274	9.09399	16.12524	25.15649	36.18774	49.21899
$\frac{1}{32}$	.000977	1.06348	4.12598	9.18848	16.25098	25.31348	36.37598	49.43848
$\frac{3}{64}$	.002197	1.09595	4.18970	9.28345	16.37720	25.47095	36.56470	49.65845
$\frac{1}{16}$	.003906	1.12891	4.25391	9.37891	16.50391	25.62891	36.75391	49.87891
$\frac{5}{64}$	.006104	1.16235	4.31860	9.47485	16.63110	25.78735	36.94360	50.09985
$\frac{3}{32}$	.008789	1.19629	4.38379	9.57129	16.75879	25.94629	37.13379	50.32129
$\frac{7}{64}$	.011963	1.23071	4.44946	9.66821	16.88696	26.10571	37.32446	50.54321
$\frac{1}{8}$	.015625	1.26563	4.51563	9.76563	17.01563	26.26563	37.51563	50.76563
$\frac{9}{64}$	.019775	1.30103	4.58228	9.86353	17.14478	26.42603	37.70728	50.98853
$\frac{5}{32}$	.024414	1.33691	4.64941	9.96191	17.27441	26.58691	37.89941	51.21191
$\frac{11}{64}$	.029541	1.37329	4.71704	10.06079	17.40454	26.74829	38.09204	51.43579
$\frac{3}{16}$	.035156	1.41016	4.78516	10.16016	17.53516	26.91016	38.28516	51.66016
$\frac{13}{64}$	.041260	1.44751	4.85376	10.26001	17.66626	27.07251	38.47876	51.88501
$\frac{7}{32}$	.047852	1.48535	4.92285	10.36035	17.79785	27.23535	38.67285	52.11035
$\frac{15}{64}$	.054932	1.52368	4.99243	10.46118	17.92993	27.39868	38.86743	52.33618
$\frac{1}{4}$	.062500	1.56250	5.06250	10.56250	18.06250	27.56250	39.06250	52.56250
$\frac{17}{64}$	.070557	1.60181	5.13306	10.66431	18.19556	27.72681	39.25806	52.78931
$\frac{9}{32}$	.079102	1.64160	5.20410	10.76660	18.32910	27.89160	39.45410	53.01660
$\frac{19}{64}$	.088135	1.68188	5.27563	10.86938	18.46313	28.05688	39.65063	53.24438
$\frac{5}{16}$	.097656	1.72266	5.34766	10.97266	18.59766	28.22266	39.84766	53.47266
$\frac{21}{64}$	.107666	1.76392	5.42017	11.07642	18.73267	28.38892	40.04517	53.70142
$\frac{11}{32}$	.118164	1.80566	5.49316	11.18066	18.86816	28.55566	40.24316	53.93066
$\frac{23}{64}$	.129151	1.84790	5.56665	11.28540	19.00415	28.72290	40.44165	54.16040
$\frac{3}{8}$	.140625	1.89063	5.64063	11.39063	19.14063	28.89063	40.64063	54.39063
$\frac{25}{64}$	.152588	1.93384	5.71509	11.49634	19.27759	29.05884	40.84009	54.62134
$\frac{13}{32}$	.165039	1.97754	5.79004	11.60254	19.41504	29.22754	41.04004	54.85254
$\frac{27}{64}$	.177979	2.02173	5.86548	11.70923	19.55298	29.39673	41.24048	55.08423
$\frac{7}{16}$	.191406	2.06641	5.94141	11.81641	19.69141	29.56641	41.44141	55.31641

Added Fractions to Sixty-fourths

13/64	.205322	2.11157	6.01782	11.92407	19.83032	29.73657	41.64282	55.54907
7/32	.219726	2.15723	6.09473	12.03223	19.96973	29.90723	41.84473	55.78223
15/64	.234619	2.20337	6.17212	12.14087	20.10962	30.07837	42.04712	56.01587
1/4	.250000	2.25000	6.25000	12.25000	20.25000	30.25000	42.25000	56.25000
17/64	.265869	2.29712	6.32837	12.35962	20.39087	30.42212	42.45337	56.48462
9/32	.282227	2.34473	6.40723	12.46973	20.53223	30.59473	42.65723	56.71973
19/64	.299072	2.39282	6.48657	12.58032	20.67407	30.76782	42.86157	56.95532
5/16	.316406	2.44141	6.56641	12.69141	20.81641	30.94141	43.06641	57.19141
21/64	.334229	2.49048	6.64673	12.80298	20.95923	31.11548	43.27173	57.42798
11/32	.352539	2.54004	6.72754	12.91504	21.10254	31.29004	43.47754	57.66504
23/64	.371338	2.59009	6.80884	13.02759	21.24634	31.46509	43.68384	57.90259
3/8	.390625	2.64063	6.89063	13.14063	21.39063	31 64063	43.89063	58.14063
25/64	.410400	2.69165	6.97290	13.25415	21.53540	31.81665	44.09790	58.37915
13/32	.430664	2.74316	7.05566	13.36816	21.68066	31.99316	44.30566	58.61816
27/64	.451416	2.79517	7.13892	13.48267	21.82642	32.17017	44.51392	58.85767
7/16	.472656	2.84766	7.22266	13.59766	21.97266	32.34766	44.72266	59.09766
29/64	.494385	2.90063	7.30688	13.71313	22.11938	32.52563	44.93188	59.33813
15/32	.516602	2.95410	7.39160	13.82910	22.26660	32.70410	45.14160	59.57910
31/64	.539307	3.00806	7.47681	13.94556	22.41431	32.88306	45.35181	59.82056
1/2	.562500	3.06250	7.56250	14.06250	22.56250	33.06250	45.56250	60.06250
33/64	.586182	3.11743	7.64868	14.17993	22.71118	33.24243	45.77368	60.30493
17/32	.610352	3.17285	7.73535	14.29785	22.86035	33.42285	45.98535	60.54785
35/64	.635010	3.22876	7.82251	14.41626	23.01001	33.60376	46.19751	60.79126
9/16	.660156	3.28516	7.91016	14.53516	23.16016	33.78516	46.41016	61.03516
37/64	.685791	3.34204	7.99829	14.65454	23.31079	33.96704	46.62329	61.27954
19/32	.711914	3.39941	8.08691	14.77441	23.46191	34.14941	46.83691	61.52441
39/64	.738526	3.45728	8.17603	14.89478	23.61353	34.33228	47.05103	61.76978
5/8	.765625	3.51563	8.26563	15.01563	23.76563	34.51563	47.26563	62.01563
41/64	.793213	3.57446	8.35571	15.13696	23.91821	34.69946	47.48071	62.26196
21/32	.821289	3.63378	8.44629	15.25879	24.07129	34.88379	47.69629	62.50879
43/64	.849854	3.69360	8.53735	15.38110	24.22485	35.06860	47.91235	62.75610
11/16	.878906	3.75391	8.62891	15.50391	24.37891	35.25391	48.12891	63.00391
45/64	.908447	3.81470	8.72095	15.62720	24.53345	35.43970	48.34595	63.25220
23/32	.938477	3.87598	8.81348	15.75098	24.68848	35.62598	48.56348	63.50098
47/64	.968994	3.93774	8.90649	15.87524	24.84399	35.81274	48.78149	63.75024

Decimal Equivalents, Squares, Square Roots, Cubes and Cube Roots, of Fractions; Circumferences and Areas of Circles from $\frac{1}{64}$ to 1 inch

Fraction	Dec. Equiv.	Square	Sq. Root	Cube	Cube Root	Circum. Circle	Area Circle
$\frac{1}{64}$	.015625	.000244	.1250	.000003815	.2500	.04909	.000192
$\frac{1}{32}$	.03125	.0009765	.1768	.00003052	.3150	.09818	.000767
$\frac{3}{64}$	.046875	.002197	.2165	.000103	.3606	.1473	.001726
$\frac{1}{16}$	.0625	.003906	.2500	.0002442	.3968	.1963	.003068
$\frac{5}{64}$	.078125	.006104	.2795	.0004768	.4275	.2455	.004794
$\frac{3}{32}$	.09375	.008789	.3062	.0008240	.4543	.2945	.006903
$\frac{7}{64}$	.109375	.01196	.3307	.001308	.4782	.3436	.009396
$\frac{1}{8}$	.1250	.01563	.3535	.001953	.5000	.3927	.01228
$\frac{9}{64}$	.140625	.01978	.3750	.002781	.5200	.4438	.01553
$\frac{5}{32}$	.15625	.02441	.3953	.003815	.5386	.4909	.01916
$\frac{11}{64}$	.171875	.02954	.4161	.005078	.5560	.5400	.02321
$\frac{3}{16}$	.1875	.03516	.4330	.006592	.5724	.5890	.02761
$\frac{13}{64}$	.203125	.04126	.4507	.008381	.5878	.6381	.03241
$\frac{7}{32}$	.21875	.04786	.4677	.01047	.6025	.6872	.03758
$\frac{15}{64}$	.234375	.05493	.4841	.01287	.6166	.7363	.04314
$\frac{1}{4}$	.2500	.0625	.5000	.01562	.6300	.7854	.04909
$\frac{17}{64}$	.265625	.07056	.5154	.01874	.6428	.8345	.05541
$\frac{9}{32}$	.28125	.07910	.5303	.02225	.6552	.8836	.06213
$\frac{19}{64}$	.296875	.08813	.5449	.02616	.6671	.9327	.06922
$\frac{5}{16}$	.3125	.09766	.5590	.03052	.6786	.9817	.07670
$\frac{21}{64}$	.328125	.1077	.5728	.03533	.6897	1.031	.08456
$\frac{11}{32}$	.34375	.1182	.5863	.04062	.7005	1.080	.09281
$\frac{23}{64}$	.359375	.12913	.5995	.04641	.7110	1.129	.1014
$\frac{3}{8}$	.3750	.1406	.6124	.05273	.7211	1.178	.1104
$\frac{25}{64}$	.390625	.1526	.6250	.05960	.7310	1.227	.1226
$\frac{13}{32}$	.40625	.1650	.6374	.06705	.7406	1.276	.1296
$\frac{27}{64}$	.421875	.17800	.6495	.07508	.7500	1.325	.1398
$\frac{7}{16}$	.4375	.1914	.6614	.08374	.7592	1.374	.1503
$\frac{29}{64}$	.453125	.2053	.6732	.09304	.7681	1.424	.1613
$\frac{15}{32}$	.46875	.2197	.6847	.1030	.7768	1.473	.1726
$\frac{31}{64}$	.484375	.2346	.6960	.1136	.7853	1.522	.1843
$\frac{1}{2}$	.5000	.2500	.7071	.1250	.7937	1.571	.1963

DECIMAL EQUIVALENTS, SQUARES, SQUARE ROOTS, CUBES, CUBE ROOTS OF FRACTIONS; CIRCUMFERENCES AND AREAS OF CIRCLES FROM $\frac{1}{64}$ TO 1 INCH

Fraction	Dec. Equiv.	Square	Sq. Root	Cube	Cube Root	Circum. Circle	Area Circle
$\frac{33}{64}$	.515625	.2659	.7181	.1371	.8019	1.620	.2088
$\frac{17}{32}$	.53125	.2822	.7289	.1499	.8099	1.669	.2217
$\frac{35}{64}$	.546875	.2991	.7395	.1636	.8178	1.718	.2349
$\frac{9}{16}$	.5625	.3164	.7500	.1780	.8255	1.767	.2485
$\frac{37}{64}$	.578125	.3342	.7603	.1932	.8331	1.816	.2625
$\frac{19}{32}$	.59375	.3525	.7706	.2093	.8405	1.865	.2769
$\frac{39}{64}$	.609375	.3713	.7806	.2263	.8478	1.914	.2916
$\frac{5}{8}$	.6250	.3906	.7906	.2441	.8550	1.963	.3068
$\frac{41}{64}$	.640625	.4104	.8004	.2629	.8621	2.013	.3223
$\frac{21}{32}$	.65625	.4307	.8101	.2826	.8690	2.062	.3382
$\frac{43}{64}$	.671875	.4514	.8197	.3033	.8758	2.111	.3545
$\frac{11}{16}$	.6875	.4727	.8292	.3250	.8826	2.160	.3712
$\frac{45}{64}$	.703125	.4944	.8385	.3476	.8892	2.209	.3883
$\frac{23}{32}$	.71875	.5166	.8478	.3713	.8958	2.258	.4057
$\frac{47}{64}$	.734375	.5393	.8569	.3961	.9022	2.307	.4236
$\frac{3}{4}$	.7500	.5625	.8660	.4219	.9086	2.356	.4418
$\frac{49}{64}$	.765625	.5862	.8750	.4488	.9148	2.405	.4604
$\frac{25}{32}$	.78125	.6104	.8839	.4768	.9210	2.454	.4794
$\frac{51}{64}$	.796875	.6350	.8927	.5060	.9271	2.503	.4987
$\frac{13}{16}$	.8125	.6602	.9014	.5364	.9331	2.553	.5185
$\frac{53}{64}$	.828125	.6858	.9100	.5679	.9391	2.602	.5386
$\frac{27}{32}$	.84375	.7119	.9186	.6007	.9449	2.651	.5592
$\frac{55}{64}$	.859375	.7385	.9270	.6347	.9507	2.700	.5801
$\frac{7}{8}$	.8750	.7656	.9354	.6699	.9565	2.749	.6013
$\frac{57}{64}$	.890625	.7932	.9437	.7064	.9621	2.798	.6230
$\frac{29}{32}$	.90625	.8213	.9520	.7443	.9677	2.847	.6450
$\frac{59}{64}$	.921875	.8499	.9601	.7835	.9732	2.896	.6675
$\frac{15}{16}$	.9375	.8789	.9682	.8240	.9787	2.945	.6903
$\frac{61}{64}$	.953125	.9084	.9763	.8659	.9841	2.994	.7135
$\frac{31}{32}$	.96875	.9385	.9843	.9091	.9895	3.043	.7371
$\frac{63}{64}$	.984375	.9690	.9922	.9539	.9948	3.093	.7610
1	1	1	1	1	1	3.1416	.7854

Squares, Cubes, Square and Cube Roots of Numbers from 1 to 1000

No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
1	1	1	1.0000	1.0000	51	2601	132651	7.1414	3.7084
2	4	8	1.4142	1.2599	52	2704	140608	7.2111	3.7325
3	9	27	1.7321	1.4422	53	2809	148877	7.2801	3.7563
4	16	64	2.0000	1.5874	54	2916	157464	7.3485	3.7798
5	25	125	2.2361	1.7100	55	3025	166375	7.4162	3.8030
6	36	216	2.4495	1.8171	56	3136	175616	7.4833	3.8259
7	49	343	2.6458	1.9129	57	3249	185193	7.5498	3.8485
8	64	512	2.8284	2.0000	58	3364	195112	7.6158	3.8709
9	81	729	3.0000	2.0801	59	3481	205379	7.6811	3.8930
10	100	1000	3.1623	2.1544	60	3600	216000	7.7460	3.9149
11	121	1331	3.3166	2.2240	61	3721	226981	7.8102	3.9365
12	144	1728	3.4641	2.2894	62	3844	238328	7.8740	3.9579
13	169	2197	3.6056	2.3513	63	3969	250047	7.9373	3.9791
14	196	2744	3.7417	2.4101	64	4096	262144	8.0000	4.0000
15	225	3375	3.8730	2.4662	65	4225	274625	8.0623	4.0207
16	256	4096	4.0000	2.5198	66	4356	287496	8.1240	4.0412
17	289	4913	4.1231	2.5713	67	4489	300763	8.1854	4.0615
18	324	5832	4.2426	2.6207	68	4624	314432	8.2462	4.0817
19	361	6859	4.3589	2.6684	69	4761	328509	8.3066	4.1016
20	400	8000	4.4721	2.7144	70	4900	343000	8.3666	4.1213
21	441	9261	4.5826	2.7589	71	5041	357911	8.4261	4.1408
22	484	10648	4.6904	2.8020	72	5184	373248	8.1853	4.1602
23	529	12167	4.7958	2.8439	73	5329	389017	8.5440	4.1793
24	576	13824	4.8990	2.8845	74	5476	405224	8.6023	4.1983
25	625	15625	5.0000	2.9240	75	5625	421875	8.6603	4.2172
26	676	17576	5.0990	2.9625	76	5776	438976	8.7178	4.2358
27	729	19683	5.1962	3.0000	77	5929	456533	8.7750	4.2543
28	784	21952	5.2915	3.0366	78	6084	474552	8.8318	4.2727
29	841	24389	5.3852	3.0723	79	6241	493039	8.8882	4.2908
30	900	27000	5.4772	3.1072	80	6400	512000	8.9443	4.3089
31	961	29791	5.5678	3.1414	81	6561	531441	9.0000	4.3267
32	1024	32768	5.6569	3.1748	82	6724	551368	9.0554	4.3445
33	1089	35937	5.7446	3.2075	83	6889	571787	9.1104	4.3621
34	1156	39304	5.8310	3.2396	84	7056	592704	9.1652	4.3795
35	1225	42875	5.9161	3.2711	85	7225	614125	9.2195	4.3968
36	1296	46656	6.0000	3.3019	86	7396	636056	9.2736	4.4140
37	1369	50653	6.0828	3.3322	87	7569	658503	9.3276	4.4310
38	1444	54872	6.1644	3.3620	88	7744	681472	9.3808	4.4480
39	1521	59319	6.2450	3.3912	89	7921	704969	9.4340	4.4647
40	1600	64000	6.3246	3.4200	90	8100	729000	9.4868	4.4814
41	1681	68921	6.4031	3.4482	91	8281	753571	9.5304	4.4979
42	1764	74088	6.4807	3.4760	92	8464	778688	9.5917	4.5144
43	1849	79507	6.5574	3.5034	93	8649	804357	9.6437	4.5307
44	1936	85184	6.6332	3.5303	94	8836	830584	9.6954	4.5468
45	2025	91125	6.7082	3.5560	95	9025	857375	9.7468	4.5629
46	2116	97336	6.7823	3.5830	96	9216	884736	9.7980	4.5789
47	2209	103823	6.8557	3.6088	97	9409	912673	9.8489	4.5947
48	2304	110592	6.9282	3.6342	98	9604	941192	9.8995	4.6104
49	2401	117649	7.0000	3.6593	99	9801	970299	9.9499	4.6261
50	2500	125000	7.0711	3.6840	100	10000	1000000	10.0000	4.6416

Squares, Cubes, Square and Cube Roots of Numbers from 1 to 1000

No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
101	10201	1030301	10.0499	4.6570	151	22801	3442951	12.2882	5.3251
102	10404	1061208	10.0995	4.6723	152	23104	3511808	12.3288	5.3368
103	10609	1092727	10.1489	4.6875	153	23409	3581577	12.3693	5.3485
104	10816	1124864	10.1980	4.7027	154	23716	3652264	12.4097	5.3601
105	11025	1157625	10.2470	4.7177	155	24025	3723875	12.4499	5.3717
106	11236	1191016	10.2956	4.7326	156	24336	3796416	12.4900	5.3832
107	11449	1225043	10.3441	4.7475	157	24649	3869893	12.5300	5.3947
108	11664	1259712	10.3923	4.7622	158	24964	3944312	12.5698	5.4061
109	11881	1295029	10.4403	4.7769	159	25281	4019679	12.6095	5.4175
110	12100	1331000	10.4881	4.7914	160	25600	4096000	12.6491	5.4288
111	12321	1367631	10.5357	4.8059	161	25921	4173281	12.6886	5.4401
112	12544	1404928	10.5830	4.8203	162	26244	4251528	12.7279	5.4514
113	12769	1442897	10.6301	4.8346	163	26569	4330747	12.7671	5.4626
114	12996	1481544	10.6771	4.8488	164	26896	4410944	12.8062	5.4737
115	13225	1520875	10.7238	4.8629	165	27225	4492125	12.8452	5.4848
116	13456	1560896	10.7703	4.8770	166	27556	4574296	12.8841	5.4959
117	13689	1601613	10.8167	4.8910	167	27889	4657463	12.9228	5.5069
118	13924	1643032	10.8628	4.9049	168	28224	4741632	12.9615	5.5178
119	14161	1685159	10.9087	4.9187	169	28561	4826809	13.0000	5.5288
120	14400	1728000	10.9545	4.9324	170	28900	4913000	13.0384	5.5397
121	14641	1771561	11.0000	4.9461	171	29241	5000211	13.0767	5.5505
122	14884	1815848	11.0454	4.9597	172	29584	5088448	13.1149	5.5613
123	15129	1860867	11.0905	4.9732	173	29929	5177717	13.1529	5.5721
124	15376	1906624	11.1355	4.9866	174	30276	5268024	13.1909	5.5828
125	15625	1953125	11.1803	5.0000	175	30625	5359375	13.2288	5.5934
126	15876	2000376	11.2250	5.0133	176	30976	5451776	13.2665	5.6041
127	16129	2048383	11.2694	5.0265	177	31329	5545233	13.3041	5.6147
128	16384	2097152	11.3137	5.0397	178	31684	5639752	13.3417	5.6252
129	16641	2146689	11.3578	5.0528	179	32041	5735339	13.3791	5.6357
130	16900	2197000	11.4018	5.0658	180	32400	5832000	13.4164	5.6462
131	17161	2248091	11.4455	5.0788	181	32761	5929741	13.4536	5.6567
132	17424	2299968	11.4891	5.0916	182	33124	6028568	13.4907	5.6671
133	17689	2352637	11.5326	5.1045	183	33489	6128487	13.5277	5.6774
134	17956	2406104	11.5758	5.1172	184	33856	6229504	13.5647	5.6877
135	18225	2460375	11.6190	5.1299	185	34225	6331625	13.6015	5.6980
136	18496	2515456	11.6619	5.1426	186	34596	6434856	13.6382	5.7083
137	18769	2571353	11.7047	5.1551	187	34969	6539203	13.6748	5.7185
138	19044	2628072	11.7473	5.1676	188	35344	6644672	13.7113	5.7287
139	19321	2685619	11.7898	5.1801	189	35721	6751269	13.7477	5.7388
140	19600	2744000	11.8322	5.1925	190	36100	6859000	13.7840	5.7489
141	19881	2803221	11.8743	5.2048	191	36481	6967871	13.8203	5.7590
142	20164	2863288	11.9164	5.2171	192	36864	7077888	13.8564	5.7690
143	20449	2924207	11.9583	5.2293	193	37249	7189057	13.8924	5.7790
144	20736	2985984	12.0000	5.2415	194	37636	7301384	13.9284	5.7890
145	21025	3048625	12.0416	5.2536	195	38025	7414875	13.9642	5.7989
146	21316	3112136	12.0830	5.2656	196	38416	7529536	14.0000	5.8088
147	21609	3176523	12.1244	5.2776	197	38809	7645373	14.0357	5.8186
148	21904	3241792	12.1655	5.2896	198	39204	7762392	14.0712	5.8285
149	22201	3307949	12.2066	5.3015	199	39601	7880599	14.1067	5.8383
150	22500	3375000	12.2474	5.3133	200	40000	8000000	14.1421	5.8480

Squares, Cubes, Square and Cube Roots of Numbers from 1 to 1000

No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
201	40401	8120601	14.1774	5.8578	251	63001	15813251	15.8430	6.3080
202	40804	8242408	14.2127	5.8675	252	63504	16003008	15.8745	6.3164
203	41209	8365427	14.2478	5.8771	253	64009	16194277	15.9060	6.3247
204	41616	8489664	14.2829	5.8868	254	64516	16387064	15.9374	6.3330
205	42025	8615125	14.3178	5.8964	255	65025	16581375	15.9687	6.3413
206	42436	8741816	14.3527	5.9059	256	65536	16777216	16.0000	6.3496
207	42849	8869743	14.3875	5.9155	257	66049	16974593	16.0312	6.3579
208	43264	8998912	14.4222	5.9250	258	66564	17173512	16.0624	6.3661
209	43681	9129329	14.4568	5.9345	259	67081	17373979	16.0935	6.3743
210	44100	9261000	14.4914	5.9439	260	67600	17576000	16.1245	6.3825
211	44521	9393931	14.5258	5.9533	261	68121	17779581	16.1555	6.3907
212	44944	9528128	14.5602	5.9627	262	68644	17984728	16.1864	6.3988
213	45369	9663597	14.5945	5.9721	263	69169	18191447	16.2173	6.4070
214	45796	9800344	14.6287	5.9814	264	69696	18399744	16.2481	6.4151
215	46225	9938375	14.6629	5.9907	265	70225	18609625	16.2788	6.4232
216	46656	10077696	14.6969	6.0000	266	70756	18821096	16.3095	6.4312
217	47089	10218313	14.7309	6.0092	267	71289	19034163	16.3401	6.4393
218	47524	10360232	14.7648	6.0185	268	71824	19248832	16.3707	6.4473
219	47961	10503459	14.7986	6.0277	269	72361	19465109	16.4012	6.4553
220	48400	10648000	14.8324	6.0368	270	72900	19683000	16.4317	6.4633
221	48841	10793861	14.8661	6.0459	271	73441	19902511	16.4621	6.4713
222	49284	10941048	14.8997	6.0550	272	73984	20123648	16.4924	6.4792
223	49729	11089567	14.9332	6.0641	273	74529	20346417	16.5227	6.4872
224	50176	11239424	14.9666	6.0732	274	75076	20570824	16.5529	6.4951
225	50625	11390625	15.0000	6.0822	275	75625	20796875	16.5831	6.5030
226	51076	11543176	15.0333	6.0912	276	76176	21024576	16.6132	6.5108
227	51529	11697083	15.0665	6.1002	277	76729	21253933	16.6433	6.5187
228	51984	11852352	15.0997	6.1091	278	77284	21484952	16.6733	6.5265
229	52441	12008989	15.1327	6.1180	279	77841	21717639	16.7033	6.5343
230	52900	12167000	15.1658	6.1269	280	78400	21952000	16.7332	6.5421
231	53361	12326391	15.1987	6.1358	281	78961	22188041	16.7631	6.5499
232	53824	12487168	15.2315	6.1446	282	79524	22425768	16.7929	6.5577
233	54289	12649337	15.2643	6.1534	283	80089	22665187	16.8226	6.5654
234	54756	12812904	15.2971	6.1622	284	80656	22906304	16.8523	6.5731
235	55225	12977875	15.3297	6.1710	285	81225	23149125	16.8819	6.5808
236	55696	13144256	15.3623	6.1797	286	81796	23393656	16.9115	6.5885
237	56169	13312053	15.3948	6.1885	287	82369	23639903	16.9411	6.5962
238	56644	13481272	15.4272	6.1972	288	82944	23887872	16.9706	6.6039
239	57121	13651919	15.4596	6.2058	289	83521	24137569	17.0000	6.6115
240	57600	13824000	15.4919	6.2145	290	84100	24389000	17.0294	6.6191
241	58081	13997521	15.5242	6.2231	291	84681	24642171	17.0587	6.6267
242	58564	14172488	15.5563	6.2317	292	85264	24897088	17.0880	6.6343
243	59049	14348907	15.5885	6.2403	293	85849	25153757	17.1172	6.6419
244	59536	14526784	15.6205	6.2488	294	86436	25412184	17.1464	6.6494
245	60025	14706125	15.6525	6.2573	295	87025	25672375	17.1756	6.6569
246	60516	14886936	15.6844	6.2658	296	87616	25933336	17.2047	6.6644
247	61009	15069223	15.7162	6.2743	297	88209	26198073	17.2337	6.6719
248	61504	15252992	15.7480	6.2828	298	88804	26463592	17.2627	6.6794
249	62001	15438249	15.7797	6.2912	299	89401	26730899	17.2916	6.6869
250	62500	15625000	15.8114	6.2996	300	90000	27000000	17.3205	6.6943

Squares, Cubes, Square and Cube Roots of Numbers from 1 to 1000

No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
301	90601	27270901	17.3494	6.7018	351	123201	43243551	18.7350	7.0540
302	91204	27543608	17.3781	6.7092	352	123904	43614208	18.7617	7.0607
303	91809	27818127	17.4069	6.7166	353	124609	43989977	18.7883	7.0674
304	92416	28094464	17.4356	6.7240	354	125316	44367864	18.8149	7.0740
305	93025	28372625	17.4642	6.7313	355	126025	44748875	18.8414	7.0807
306	93636	28652616	17.4929	6.7387	356	126736	45118016	18.8680	7.0873
307	94249	28934443	17.5214	6.7460	357	127449	45499293	18.8944	7.0940
308	94864	29218112	17.5499	6.7533	358	128164	45882712	18.9209	7.1006
309	95481	29503629	17.5784	6.7606	359	128881	46268279	18.9473	7.1072
310	96100	29791000	17.6068	6.7679	360	129600	46656000	18.9737	7.1138
311	96721	30080231	17.6352	6.7752	361	130321	47045881	19.0000	7.1204
312	97344	30373328	17.6635	6.7824	362	131044	47437928	19.0263	7.1269
313	97969	30664297	17.6918	6.7897	363	131769	47832147	19.0526	7.1335
314	98596	30959144	17.7200	6.7969	364	132496	48228544	19.0788	7.1400
315	99225	31255875	17.7482	6.8041	365	133225	48627125	19.1050	7.1466
316	99856	31554496	17.7764	6.8113	366	133956	49027896	19.1311	7.1531
317	100489	31855013	17.8045	6.8185	367	134689	49430863	19.1572	7.1596
318	101124	32157432	17.8326	6.8256	368	135424	49836032	19.1833	7.1661
319	101761	32461759	17.8606	6.8328	369	136161	50243409	19.2094	7.1726
320	102400	32768000	17.8885	6.8399	370	136900	50653000	19.2354	7.1791
321	103041	33076161	17.9165	6.8470	371	137641	51064811	19.2614	7.1855
322	103684	33386248	17.9444	6.8541	372	138384	51478848	19.2873	7.1920
323	104329	33698267	17.9722	6.8612	373	139129	51895117	19.3132	7.1984
324	104976	34012224	18.0000	6.8683	374	139876	52313624	19.3391	7.2048
325	105625	34328125	18.0278	6.8753	375	140625	52734375	19.3649	7.2112
326	106276	34645976	18.0555	6.8824	376	141376	53157376	19.3907	7.2177
327	106929	34965783	18.0831	6.8894	377	142129	53582633	19.4165	7.2240
328	107584	35287552	18.1108	6.8964	378	142884	54010152	19.4422	7.2304
329	108241	35611289	18.1384	6.9034	379	143641	54439939	19.4679	7.2368
330	108900	35937000	18.1659	6.9104	380	144400	54872000	19.4936	7.2432
331	109561	36264691	18.1934	6.9174	381	145161	55306341	19.5192	7.2495
332	110224	36594368	18.2209	6.9244	382	145924	55742968	19.5448	7.2558
333	110889	36926037	18.2483	6.9313	383	146689	56181887	19.5704	7.2622
334	111556	37259704	18.2757	6.9382	384	147456	56623104	19.5959	7.2685
335	112225	37595375	18.3030	6.9451	385	148225	57066625	19.6214	7.2748
336	112896	37933056	18.3303	6.9521	386	148996	57512456	19.6469	7.2811
337	113569	38272753	18.3576	6.9589	387	149769	57960603	19.6723	7.2874
338	114244	38614472	18.3848	6.9658	388	150544	58411072	19.6977	7.2936
339	114921	38958219	18.4120	6.9727	389	151321	58863869	19.7231	7.2999
340	115600	39304000	18.4391	6.9795	390	152100	59319000	19.7484	7.3061
341	116281	39651821	18.4662	6.9864	391	152881	59776471	19.7737	7.3124
342	116964	40001688	18.4932	6.9932	392	153664	60236288	19.7990	7.3186
343	117649	40353607	18.5203	7.0000	393	154449	60698457	19.8242	7.3248
344	118336	40707584	18.5472	7.0068	394	155236	61162984	19.8494	7.3310
345	119025	41063625	18.5742	7.0136	395	156025	61629875	19.8746	7.3372
346	119716	41421736	18.6011	7.0203	396	156816	62099136	19.8997	7.3434
347	120409	41781923	18.6279	7.0271	397	157609	62570773	19.9249	7.3496
348	121104	42144192	18.6548	7.0338	398	158404	63044792	19.9499	7.3558
349	121801	42508549	18.6815	7.0406	399	159201	63521199	19.9750	7.3619
350	122500	42875000	18.7083	7.0473	400	160000	64000000	20.0000	7.3681

Squares, Cubes, Square and Cube Roots of Numbers from 1 to 1000

No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
401	160801	64481201	20.0250	7.3742	451	203401	91733851	21.2368	7.6688
402	161604	64964808	20.0499	7.3803	452	204304	92345408	21.2603	7.6744
403	162409	65450827	20.0749	7.3864	453	205209	92959677	21.2838	7.6800
404	163216	65930264	20.0998	7.3925	454	206116	93576664	21.3073	7.6857
405	164025	66430125	20.1246	7.3986	455	207025	94196375	21.3307	7.6914
406	164836	66923416	20.1494	7.4047	456	207936	94818816	21.3542	7.6970
407	165649	67419143	20.1742	7.4108	457	208849	95443993	21.3776	7.7026
408	166464	67917312	20.1990	7.4169	458	209764	96071912	21.4009	7.7082
409	167281	68417929	20.2237	7.4229	459	210681	96702579	21.4243	7.7138
410	168100	68921000	20.2485	7.4290	460	211600	97336000	21.4476	7.7194
411	168921	69426531	20.2731	7.4350	461	212521	97972181	21.4709	7.7250
412	169744	69934528	20.2978	7.4410	462	213444	98611128	21.4942	7.7306
413	170569	70444997	20.3224	7.4470	463	214369	99252847	21.5174	7.7362
414	171396	70957944	20.3470	7.4530	464	215296	99897344	21.5407	7.7418
415	172225	71473375	20.3715	7.4590	465	216225	100544625	21.5639	7.7473
416	173056	71991296	20.3961	7.4650	466	217156	101194696	21.5870	7.7529
417	173889	72511713	20.4206	7.4710	467	218089	101847563	21.6102	7.7584
418	174724	73034632	20.4450	7.4770	468	219024	102503232	21.6333	7.7639
419	175561	73560059	20.4695	7.4829	469	219961	103161709	21.6564	7.7695
420	176400	74088000	20.4939	7.4889	470	220900	103823000	21.6795	7.7750
421	177241	74618461	20.5183	7.4948	471	221841	104487111	21.7025	7.7805
422	178084	75151448	20.5426	7.5007	472	222784	105154048	21.7256	7.7860
423	178929	75686967	20.5670	7.5067	473	223729	105823817	21.7486	7.7915
424	179776	76225024	20.5913	7.5126	474	224676	106496424	21.7715	7.7970
425	180625	76765625	20.6155	7.5185	475	225625	107171875	21.7945	7.8025
426	181476	77308776	20.6398	7.5244	476	226576	107850176	21.8174	7.8079
427	182329	77854483	20.6640	7.5302	477	227529	108531333	21.8403	7.8134
428	183184	78402752	20.6882	7.5361	478	228484	109215352	21.8632	7.8188
429	184041	78953589	20.7123	7.5420	479	229441	109902239	21.8861	7.8243
430	184900	79507000	20.7364	7.5478	480	230400	110592000	21.9089	7.8297
431	185761	80062991	20.7605	7.5537	481	231361	111284641	21.9317	7.8352
432	186624	80621568	20.7846	7.5595	482	232324	111980168	21.9545	7.8406
433	187489	81182737	20.8087	7.5654	483	233289	112678587	21.9773	7.8460
434	188356	81746504	20.8327	7.5712	484	234256	113379904	22.0000	7.8514
435	189225	82312875	20.8567	7.5770	485	235225	114084125	22.0227	7.8568
436	190096	82881856	20.8806	7.5828	486	236196	114791256	22.0454	7.8622
437	190969	83453453	20.9045	7.5886	487	237169	115501303	22.0681	7.8676
438	191844	84027672	20.9284	7.5944	488	238144	116214272	22.0907	7.8730
439	192721	84604519	20.9523	7.6001	489	239121	116930169	22.1133	7.8784
440	193600	85184000	20.9762	7.6059	490	240100	117649000	22.1359	7.8837
441	194481	85766121	21.0000	7.6117	491	241081	118370771	22.1585	7.8891
442	195364	86350888	21.0238	7.6174	492	242064	119095488	22.1811	7.8944
443	196249	86938307	21.0476	7.6232	493	243049	119823157	22.2036	7.8998
444	197136	87528384	21.0713	7.6289	494	244036	120553784	22.2261	7.9051
445	198025	88121125	21.0950	7.6346	495	245025	121287375	22.2486	7.9105
446	198916	88716536	21.1187	7.6403	496	246016	122023936	22.2711	7.9158
447	199809	89314623	21.1424	7.6460	497	247009	122763473	22.2935	7.9211
448	200704	89915392	21.1660	7.6517	498	248004	123505992	22.3159	7.9264
449	201601	90518849	21.1896	7.6574	499	249001	124251499	22.3383	7.9317
450	202500	91125000	21.2132	7.6631	500	250000	125000000	22.3607	7.9370

Squares, Cubes, Square and Cube Roots of Numbers from 1 to 1000

No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
501	251001	125751501	22.3830	7.9423	551	303601	167284151	23.4734	8.1982
502	252004	126506008	22.4054	7.9476	552	304704	168196608	23.4947	8.2031
503	253009	127263527	22.4277	7.9528	553	305809	169112377	23.5160	8.2081
504	254016	128024064	22.4499	7.9581	554	306916	170031464	23.5372	8.2130
505	255025	128787625	22.4722	7.9634	555	308025	170953875	23.5584	8.2180
506	256036	129554216	22.4944	7.9686	556	309136	171879616	23.5797	8.2229
507	257049	130323843	22.5167	7.9739	557	310249	172808693	23.6008	8.2278
508	258064	131096512	22.5389	7.9791	558	311364	173741112	23.6220	8.2327
509	259081	131872229	22.5610	7.9843	559	312481	174676879	23.6432	8.2377
510	260100	132651000	22.5832	7.9896	560	313600	175616000	23.6643	8.2426
511	261121	133432831	22.6053	7.9948	561	314721	176558481	23.6854	8.2475
512	262144	134217728	22.6274	8.0000	562	315844	177504328	23.7065	8.2524
513	263169	135005697	22.6495	8.0052	563	316969	178453547	23.7276	8.2573
514	264196	135796744	22.6716	8.0104	564	318096	179406144	23.7487	8.2621
515	265225	136590875	22.6936	8.0156	565	319225	180362125	23.7697	8.2670
516	266256	137388096	22.7156	8.0208	566	320356	181321496	23.7908	8.2719
517	267289	138188413	22.7376	8.0260	567	321489	182284263	23.8118	8.2768
518	268324	138991832	22.7596	8.0311	568	322624	183250432	23.8328	8.2816
519	269361	139798359	22.7816	8.0363	569	323761	184220009	23.8537	8.2865
520	270400	140608000	22.8035	8.0415	570	324900	185193000	23.8747	8.2913
521	271441	141420761	22.8254	8.0466	571	326041	186169411	23.8956	8.2962
522	272484	142236648	22.8473	8.0517	572	327184	187149248	23.9165	8.3010
523	273529	143055667	22.8692	8.0569	573	328329	188132517	23.9374	8.3059
524	274576	143878824	22.8910	8.0620	574	329476	189119224	23.9583	8.3107
525	275625	144703125	22.9129	8.0671	575	330625	190109375	23.9792	8.3155
526	276676	145531576	22.9347	8.0723	576	331776	191102976	24.0000	8.3203
527	277729	146363183	22.9565	8.0774	577	332929	192100033	24.0208	8.3251
528	278784	147197952	22.9783	8.0825	578	334084	193100552	24.0416	8.3300
529	279841	148035889	23.0000	8.0876	579	335241	194104539	24.0624	8.3348
530	280900	148877000	23.0217	8.0927	580	336400	195112000	24.0832	8.3396
531	281961	149721291	23.0434	8.0978	581	337561	196122941	24.1039	8.3443
532	283024	150568768	23.0651	8.1028	582	338724	197137368	24.1247	8.3491
533	284089	151419437	23.0868	8.1079	583	339889	198155287	24.1454	8.3539
534	285156	152273304	23.1084	8.1130	584	341056	199176704	24.1661	8.3587
535	286225	153130375	23.1301	8.1180	585	342225	200201625	24.1868	8.3634
536	287296	153990656	23.1517	8.1231	586	343396	201230056	24.2074	8.3682
537	288369	154854153	23.1733	8.1281	587	344569	202262003	24.2281	8.3730
538	289444	155720872	23.1948	8.1332	588	345744	203297472	24.2487	8.3777
539	290521	156590819	23.2164	8.1382	589	346921	204336469	24.2693	8.3825
540	291600	157464000	23.2379	8.1433	590	348100	205379000	24.2899	8.3872
541	292681	158340421	23.2594	8.1483	591	349281	206425071	24.3105	8.3919
542	293764	159220088	23.2809	8.1533	592	350464	207474688	24.3311	8.3967
543	294849	160103007	23.3024	8.1583	593	351649	208527857	24.3516	8.4014
544	295936	160989184	23.3238	8.1633	594	352836	209584584	24.3721	8.4061
545	297025	161878625	23.3452	8.1683	595	354025	210644875	24.3926	8.4108
546	298116	162771336	23.3666	8.1733	596	355216	211708736	24.4131	8.4155
547	299209	163667323	23.3880	8.1783	597	356409	212776173	24.4336	8.4202
548	300304	164566592	23.4094	8.1833	598	357604	213847192	24.4540	8.4249
549	301401	165469149	23.4307	8.1882	599	358801	214921799	24.4745	8.4296
550	302500	166375000	23.4521	8.1932	600	360000	216000000	24.4949	8.4343

Squares, Cubes, Square and Cube Roots of Numbers from 1 to 1000

No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
601	361201	217081801	24.5153	8.4390	651	423801	275894451	25.5147	8.6668
602	362404	218167208	24.5357	8.4437	652	425104	277167808	25.5343	8.6713
603	363609	219250227	24.5561	8.4484	653	426409	278445077	25.5539	8.6757
604	364816	220348864	24.5764	8.4530	654	427716	279726264	25.5734	8.6801
605	366025	221445125	24.5967	8.4577	655	429025	281011375	25.5930	8.6845
606	367236	222545016	24.6171	8.4623	656	430336	282300416	25.6125	8.6890
607	368449	223648543	24.6374	8.4670	657	431649	283593393	25.6320	8.6934
608	369664	224755712	24.6577	8.4716	658	432964	284890312	25.6515	8.6978
609	370881	225866529	24.6779	8.4763	659	434281	286191179	25.6710	8.7022
610	372100	226981000	24.6982	8.4809	660	435600	287496000	25.6905	8.7066
611	373321	228099131	24.7184	8.4856	661	436921	288804781	25.7099	8.7110
612	374544	229220928	24.7386	8.4902	662	438244	290117528	25.7294	8.7154
613	375769	230346397	24.7588	8.4948	663	439569	291434247	25.7488	8.7198
614	376996	231475544	24.7790	8.4994	664	440896	292754944	25.7682	8.7241
615	378225	232608375	24.7992	8.5040	665	442225	294079625	25.7876	8.7285
616	379456	233744896	24.8193	8.5086	666	443556	295408296	25.8070	8.7329
617	380689	234885113	24.8395	8.5132	667	444889	296740963	25.8263	8.7373
618	381924	236029032	24.8596	8.5178	668	446224	298077632	25.8457	8.7416
619	383161	237176659	24.8797	8.5224	669	447561	299418309	25.8650	8.7460
620	384400	238328000	24.8998	8.5270	670	448900	300763000	25.8844	8.7503
621	385641	239483061	24.9199	8.5316	671	450241	302111711	25.9037	8.7547
622	386884	240641848	24.9399	8.5362	672	451584	303464448	25.9230	8.7590
623	388129	241804367	24.9600	8.5408	673	452929	304821217	25.9422	8.7634
624	389376	242970624	24.9800	8.5453	674	454276	306182024	25.9615	8.7677
625	390625	244140625	25.0000	8.5499	675	455625	307546875	25.9808	8.7721
626	391876	245314376	25.0200	8.5544	676	456976	308915776	26.0000	8.7764
627	393129	246491883	25.0400	8.5590	677	458329	310288733	26.0192	8.7807
628	394384	247673152	25.0599	8.5635	678	459684	311665752	26.0384	8.7850
629	395641	248858189	25.0799	8.5681	679	461041	313046839	26.0576	8.7893
630	396900	250047000	25.0998	8.5726	680	462400	314432000	26.0768	8.7937
631	398161	251239591	25.1197	8.5772	681	463761	315821241	26.0960	8.7980
632	399424	252435968	25.1396	8.5817	682	465124	317214568	26.1151	8.8023
633	400689	253636137	25.1595	8.5862	683	466489	318611987	26.1343	8.8066
634	401956	254840104	25.1794	8.5907	684	467856	320013504	26.1534	8.8109
635	403225	256047875	25.1992	8.5952	685	469225	321419125	26.1725	8.8152
636	404496	257259456	25.2190	8.5997	686	470596	322828856	26.1916	8.8194
637	405769	258474853	25.2389	8.6043	687	471969	324242703	26.2107	8.8237
638	407044	259694072	25.2587	8.6088	688	473344	325660672	26.2298	8.8280
639	408321	260917119	25.2784	8.6132	689	474721	327082769	26.2488	8.8323
640	409600	262144000	25.2982	8.6177	690	476100	328509000	26.2679	8.8366
641	410881	263374721	25.3180	8.6222	691	477481	329939371	26.2869	8.8408
642	412164	264609288	25.3377	8.6267	692	478864	331373888	26.3059	8.8451
643	413449	265847707	25.3574	8.6312	693	480249	332812557	26.3249	8.8493
644	414736	267089984	25.3772	8.6357	694	481636	334255384	26.3439	8.8536
645	416025	268336125	25.3969	8.6401	695	483025	335702375	26.3629	8.8578
646	417316	269586136	25.4165	8.6446	696	484416	337153536	26.3818	8.8621
647	418609	270840023	25.4362	8.6490	697	485809	338608873	26.4008	8.8663
648	419904	272097792	25.4558	8.6535	698	487204	340068392	26.4197	8.8706
649	421201	273359449	25.4755	8.6579	699	488601	341532099	26.4386	8.8748
650	422500	274625000	25.4951	8.6624	700	490000	343000000	26.4575	8.8790

Squares, Cubes, Square and Cube Roots of Numbers from 1 to 1000

No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
701	491401	344472101	26.4764	8.8833	751	564001	423564751	27.4044	9.0896
702	492804	345948408	26.4953	8.8875	752	565504	425250008	27.4226	9.0937
703	494209	347428927	26.5141	8.8917	753	567009	426957777	27.4408	9.0977
704	495616	348913664	26.5330	8.8959	754	568516	428681064	27.4591	9.1017
705	497025	350402625	26.5518	8.9001	755	570025	430368875	27.4773	9.1057
706	498436	351895816	26.5707	8.9043	756	571536	432081216	27.4955	9.1098
707	499849	353393243	26.5895	8.9085	757	573049	433798093	27.5136	9.1138
708	501264	354894912	26.6083	8.9127	758	574564	435510512	27.5318	9.1178
709	502681	356400829	26.6271	8.9169	759	576081	437245479	27.5500	9.1218
710	504100	357911000	26.6458	8.9211	760	577600	438976000	27.5681	9.1258
711	505521	359425431	26.6646	8.9253	761	579121	440711081	27.5862	9.1298
712	506944	360944128	26.6833	8.9295	762	580644	442450728	27.6043	9.1338
713	508369	362467097	26.7021	8.9337	763	582169	444194947	27.6225	9.1378
714	509796	363994344	26.7208	8.9378	764	583696	445943744	27.6405	9.1418
715	511225	365525875	26.7395	8.9420	765	585225	447697125	27.6586	9.1458
716	512656	367061696	26.7582	8.9462	766	586756	449455096	27.6767	9.1498
717	514089	368601813	26.7769	8.9503	767	588289	451217663	27.6948	9.1537
718	515524	370146232	26.7955	8.9545	768	589824	452984832	27.7128	9.1577
719	516961	371694959	26.8142	8.9587	769	591361	454756609	27.7308	9.1617
720	518400	373248000	26.8328	8.9628	770	592900	456533000	27.7489	9.1657
721	519841	374805361	26.8514	8.9670	771	594441	458314011	27.7669	9.1696
722	521284	376367048	26.8701	8.9711	772	595984	460099648	27.7849	9.1736
723	522729	377933067	26.8887	8.9752	773	597529	461889917	27.8029	9.1775
724	524176	379503424	26.9072	8.9794	774	599076	463684824	27.8209	9.1815
725	525625	381078125	26.9258	8.9835	775	600625	465484375	27.8388	9.1855
726	527076	382657176	26.9444	8.9876	776	602176	467288576	27.8568	9.1894
727	528529	384240583	26.9629	8.9918	777	603729	469097433	27.8747	9.1933
728	529984	385828352	26.9815	8.9959	778	605284	470910952	27.8927	9.1973
729	531441	387420489	27.0000	9.0000	779	606841	472729139	27.9106	9.2012
730	532900	389017000	27.0185	9.0041	780	608400	474552000	27.9285	9.2052
731	534361	390617891	27.0370	9.0082	781	609961	476379541	27.9464	9.2091
732	535824	392223168	27.0555	9.0123	782	611524	478211768	27.9643	9.2130
733	537289	393832837	27.0740	9.0164	783	613089	480048687	27.9821	9.2170
734	538756	395446904	27.0924	9.0205	784	614656	481890304	28.0000	9.2209
735	540225	397065375	27.1109	9.0246	785	616225	483736625	28.0179	9.2248
736	541696	398688256	27.1293	9.0287	786	617796	485587656	28.0357	9.2287
737	543169	400315553	27.1477	9.0328	787	619369	487443403	28.0535	9.2326
738	544644	401947272	27.1662	9.0369	788	620944	489303872	28.0713	9.2365
739	546121	403583419	27.1846	9.0410	789	622521	491169069	28.0891	9.2404
740	547600	405224000	27.2029	9.0450	790	624100	493039000	28.1069	9.2443
741	549081	406869021	27.2213	9.0491	791	625681	494913671	28.1247	9.2482
742	550564	408518488	27.2397	9.0532	792	627264	496793088	28.1425	9.2521
743	552049	410172407	27.2580	9.0572	793	628849	498677257	28.1603	9.2560
744	553536	411830784	27.2764	9.0613	794	630436	500566184	28.1780	9.2599
745	555025	413493625	27.2947	9.0654	795	632025	502459875	28.1957	9.2638
746	556516	415160936	27.3130	9.0694	796	633616	504358336	28.2135	9.2677
747	558009	416832723	27.3313	9.0735	797	635209	506261573	28.2312	9.2716
748	559504	418508992	27.3496	9.0775	798	636804	508169592	28.2489	9.2754
749	561001	420189749	27.3679	9.0816	799	638401	510082399	28.2666	9.2793
750	562500	421875000	27.3861	9.0856	800	640000	512000000	28.2843	9.2832

Squares, Cubes, Square and Cube Roots of Numbers from 1 to 1000

No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
801	641601	513922401	28.3019	9.2870	851	724201	616295051	29.1719	9.4764
802	643204	515849608	28.3196	9.2909	852	725904	618470208	29.1890	9.4801
803	644809	517781627	28.3373	9.2948	853	727609	620650477	29.2062	9.4838
804	646416	519718464	28.3549	9.2986	854	729316	622835864	29.2233	9.4875
805	648025	521660125	28.3725	9.3025	855	731025	625026375	29.2404	9.4912
806	649636	523606616	28.3901	9.3063	856	732736	627222016	29.2575	9.4949
807	651249	525557943	28.4077	9.3102	857	734449	629422793	29.2746	9.4986
808	652864	527514112	28.4253	9.3140	858	736164	631628712	29.2916	9.5023
809	654481	529475129	28.4429	9.3179	859	737881	633839779	29.3087	9.5060
810	656100	531441000	28.4605	9.3217	860	739600	636056000	29.3258	9.5097
811	657721	533411731	28.4781	9.3255	861	741321	638277381	29.3428	9.5134
812	659344	535387328	28.4956	9.3294	862	743044	640503928	29.3598	9.5171
813	660969	537367797	28.5132	9.3332	863	744769	642735647	29.3769	9.5207
814	662596	539353144	28.5307	9.3370	864	746496	644972544	29.3939	9.5244
815	664225	541343375	28.5482	9.3408	865	748225	647214625	29.4109	9.5281
816	665856	543338496	28.5657	9.3447	866	749956	649461896	29.4279	9.5317
817	667489	545338513	28.5832	9.3485	867	751689	651714363	29.4449	9.5354
818	669124	547343432	28.6007	9.3523	868	753424	653972032	29.4618	9.5391
819	670761	549353259	28.6182	9.3561	869	755161	656234909	29.4788	9.5427
820	672400	551368000	28.6356	9.3599	870	756900	658503000	29.4958	9.5464
821	674041	553387661	28.6531	9.3637	871	758641	660776311	29.5127	9.5501
822	675684	555412248	28.6705	9.3675	872	760384	663054848	29.5296	9.5537
823	677329	557441767	28.6880	9.3713	873	762129	665338617	29.5466	9.5574
824	678976	559476224	28.7054	9.3751	874	763876	667627624	29.5635	9.5610
825	680625	561515625	28.7228	9.3789	875	765625	669921875	29.5804	9.5647
826	682276	563559976	28.7402	9.3827	876	767376	672221376	29.5973	9.5683
827	683929	565609283	28.7576	9.3865	877	769129	674526133	29.6142	9.5719
828	685584	567663552	28.7750	9.3902	878	770884	676836152	29.6311	9.5756
829	687241	569722789	28.7924	9.3940	879	772641	679151439	29.6479	9.5792
830	688900	571787000	28.8097	9.3978	880	774400	681472000	29.6648	9.5828
831	690561	573856191	28.8271	9.4016	881	776161	683797841	29.6816	9.5865
832	692224	575930368	28.8444	9.4053	882	777924	686128968	29.6985	9.5901
833	693889	578009537	28.8617	9.4091	883	779689	688465387	29.7153	9.5937
834	695556	580093704	28.8791	9.4129	884	781456	690807104	29.7321	9.5973
835	697225	582182875	28.8964	9.4166	885	783225	693154125	29.7489	9.6010
836	698896	584277056	28.9137	9.4204	886	784996	695506456	29.7658	9.6046
837	700569	586376253	28.9310	9.4241	887	786769	697864103	29.7825	9.6082
838	702244	588480472	28.9482	9.4279	888	788544	700227072	29.7993	9.6118
839	703921	590589719	28.9655	9.4316	889	790321	702595369	29.8161	9.6154
840	705600	592704000	28.9828	9.4354	890	792100	704969000	29.8329	9.6190
841	707281	594823321	29.0000	9.4391	891	793881	707347971	29.8496	9.6226
842	708964	596947688	29.0172	9.4429	892	795664	709732288	29.8664	9.6262
843	710649	599077107	29.0345	9.4466	893	797449	712121957	29.8831	9.6298
844	712336	601211584	29.0517	9.4503	894	799236	714516984	29.8998	9.6334
845	714025	603351125	29.0689	9.4541	895	801025	716917375	29.9166	9.6370
846	715716	605495736	29.0861	9.4578	896	802816	719323136	29.9333	9.6406
847	717409	607645423	29.1033	9.4615	897	804609	721734273	29.9500	9.6442
848	719104	609800192	29.1204	9.4652	898	806404	724150792	29.9666	9.6477
849	720801	611960049	29.1376	9.4690	899	808201	726572699	29.9833	9.6513
850	722500	614125000	29.1548	9.4727	900	810000	729000000	30.0000	9.6549

Squares, Cubes, Square and Cube Roots of Numbers from 1 to 1000

No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
901	811801	731432701	30.0167	9.6585	951	904401	860085351	30.8383	9.8339
902	813604	733870808	30.0333	9.6629	952	906304	862801408	30.8545	9.8374
903	815409	736314327	30.0500	9.6656	953	908209	865523177	30.8707	9.8408
904	817216	738763264	30.0666	9.6692	954	910116	868250664	30.8869	9.8443
905	819025	741217625	30.0832	9.6727	955	912025	870983875	30.9031	9.8477
906	820836	743677416	30.0998	9.6763	956	913936	873722816	30.9192	9.8511
907	822649	746142643	30.1164	9.6799	957	915849	876467493	30.9354	9.8546
908	824464	748613312	30.1330	9.6834	958	917764	879217912	30.9516	9.8580
909	826281	751089429	30.1496	9.6870	959	919681	881974079	30.9677	9.8614
910	828100	753571000	30.1662	9.6905	960	921600	884736000	30.9839	9.8648
911	829921	756058031	30.1828	9.6941	961	923521	887503681	31.0000	9.8683
912	831744	758550528	30.1993	9.6976	962	925444	890277128	31.0161	9.8717
913	833569	761048497	30.2159	9.7012	963	927369	893056347	31.0322	9.8751
914	835396	763551944	30.2324	9.7047	964	929296	895841344	31.0483	9.8785
915	837225	766060875	30.2490	9.7082	965	931225	898632125	31.0644	9.8819
916	839056	768575296	30.2655	9.7118	966	933156	901428696	31.0805	9.8854
917	840889	771095213	30.2820	9.7153	967	935089	904231063	31.0966	9.8888
918	842724	773620632	30.2985	9.7188	968	937024	907039232	31.1127	9.8922
919	844561	776151559	30.3150	9.7224	969	938961	909853209	31.1288	9.8956
920	846400	778688000	30.3315	9.7259	970	940900	912673000	31.1448	9.8990
921	848241	781229961	30.3480	9.7294	971	942841	915498611	31.1609	9.9024
922	850084	783777448	30.3645	9.7329	972	944784	918330048	31.1769	9.9058
923	851929	786330467	30.3809	9.7364	973	946729	921167317	31.1929	9.9092
924	853776	788889024	30.3974	9.7400	974	948676	924010424	31.2090	9.9126
925	855625	791453125	30.4138	9.7435	975	950625	926859375	31.2250	9.9160
926	857476	794022776	30.4302	9.7470	976	952576	929714176	31.2410	9.9194
927	859329	796597983	30.4467	9.7505	977	954529	932574833	31.2570	9.9227
928	861184	799178752	30.4631	9.7540	978	956484	935441352	31.2730	9.9261
929	863041	801765089	30.4795	9.7575	979	958441	938313739	31.2890	9.9295
930	864900	804357000	30.4959	9.7610	980	960400	941192000	31.3050	9.9329
931	866761	806954491	30.5123	9.7645	981	962361	944076141	31.3209	9.9363
932	868624	809557568	30.5287	9.7680	982	964324	946966168	31.3369	9.9396
933	870489	812166237	30.5450	9.7715	983	966289	949862087	31.3528	9.9430
934	872356	814780504	30.5614	9.7750	984	968256	952763904	31.3688	9.9464
935	874225	817400375	30.5778	9.7785	985	970225	955671625	31.3847	9.9497
936	876096	820025856	30.5941	9.7819	986	972196	958585256	31.4006	9.9531
937	877969	822656953	30.6105	9.7854	987	974169	961504803	31.4166	9.9565
938	879844	825293672	30.6268	9.7889	988	976144	964430272	31.4325	9.9598
939	881721	827936019	30.6431	9.7924	989	978121	967361669	31.4484	9.9632
940	883600	830584000	30.6594	9.7959	990	980100	970299000	31.4643	9.9666
941	885481	833237621	30.6757	9.7993	991	982081	973242271	31.4802	9.9699
942	887364	835896888	30.6920	9.8028	992	984064	976191488	31.4960	9.9733
943	889249	838561807	30.7083	9.8063	993	986049	979146657	31.5119	9.9766
944	891136	841232384	30.7246	9.8097	994	988036	982107784	31.5278	9.9800
945	893025	843908625	30.7409	9.8132	995	990025	985074875	31.5436	9.9833
946	894916	846590536	30.7571	9.8167	996	992016	988047936	31.5595	9.9866
947	896809	849278123	30.7734	9.8201	997	994009	991026973	31.5753	9.9900
948	898704	851971392	30.7896	9.8236	998	996004	994011992	31.5911	9.9933
949	900601	854670349	30.8058	9.8270	999	998001	997002999	31.6070	9.9967
950	902500	857375000	30.8221	9.8305	1000	1000000	1000000000	31.6228	10.0000

Areas and Circumferences of Circles from 1 to 100

Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.
1/32	0.00077	0.098175	2	3.1416	6.28319	5	19.635	15.7080
1/16	0.00173	0.147262	1/16	3.3410	6.47953	1/16	20.129	15.9043
1/16	0.00307	0.196350	1/8	3.5466	6.67588	1/8	20.629	16.1007
3/32	0.00690	0.294524	1/16	3.7583	6.87223	1/8	21.135	16.2970
1/8	0.01227	0.392699	1/4	3.9761	7.06858	1/16	21.648	16.4934
5/32	0.01917	0.490874	5/16	4.2000	7.26493	5/16	22.166	16.6897
1/16	0.02761	0.589049	3/8	4.4301	7.46128	3/8	22.691	16.8861
7/32	0.03758	0.687223	7/16	4.6664	7.65763	7/16	23.221	17.0824
1/4	0.04909	0.785398	1/2	4.9087	7.85398	1/2	23.758	17.2788
9/32	0.06213	0.883573	9/16	5.1572	8.05033	9/16	24.301	17.4751
1/16	0.07670	0.981748	5/8	5.4119	8.24668	5/8	24.850	17.6715
11/32	0.09281	1.07992	11/16	5.6727	8.44303	11/16	25.406	17.8678
3/8	0.11045	1.17810	3/4	5.9396	8.63938	3/4	25.967	18.0642
13/32	0.12962	1.27627	13/16	6.2126	8.83573	13/16	26.535	18.2605
7/16	0.15033	1.37445	7/8	6.4918	9.03208	7/8	27.109	18.4569
15/32	0.17257	1.47262	15/16	6.7771	9.22843	15/16	27.688	18.6532
1/2	0.19635	1.57080	3	7.0686	9.42478	6	28.274	18.8496
17/32	0.22166	1.66897	1/16	7.3662	9.62113	1/8	29.465	19.2423
9/16	0.24850	1.76715	1/8	7.6699	9.81748	1/4	30.680	19.6350
19/32	0.27688	1.86532	3/16	7.9798	10.0138	3/8	31.919	20.0277
5/8	0.30680	1.96350	1/4	8.2958	10.2102	1/2	33.183	20.4204
21/32	0.33824	2.06167	5/16	8.6179	10.4065	5/8	34.472	20.8131
11/16	0.37122	2.15984	3/8	8.9462	10.6029	3/4	35.785	21.2058
23/32	0.40574	2.25802	7/16	9.2806	10.7992	7/8	37.122	21.5984
3/4	0.44179	2.35619	1/2	9.6211	10.9956	7	38.485	21.9911
25/32	0.47937	2.45437	9/16	9.9678	11.1919	1/8	39.871	22.3838
13/16	0.51849	2.55254	5/8	10.321	11.3883	1/4	41.282	22.7765
27/32	0.55914	2.65072	11/16	10.680	11.5846	3/8	42.718	23.1692
7/8	0.60132	2.74889	3/4	11.045	11.7810	1/2	44.179	23.5619
29/32	0.64504	2.84707	13/16	11.416	11.9773	5/8	45.664	23.9546
15/16	0.69029	2.94524	7/8	11.793	12.1737	3/4	47.173	24.3473
31/32	0.73708	3.04342	15/16	12.177	12.3700	7/8	48.707	24.7400
1	0.78540	3.14159	4	12.566	12.5664	8	50.265	25.1327
1/16	0.88664	3.33794	1/16	12.962	12.7627	1/8	51.849	25.5255
1/8	0.99402	3.53429	1/8	13.364	12.9591	1/4	53.456	25.9181
3/16	1.1075	3.73064	3/16	13.772	13.1554	3/8	55.088	26.3108
1/4	1.2272	3.92699	1/4	14.186	13.3518	1/2	56.745	26.7035
5/16	1.3530	4.12334	5/16	14.607	13.5481	5/8	58.426	27.0962
3/8	1.4849	4.31969	3/8	15.033	13.7445	3/4	60.132	27.4889
7/16	1.6230	4.51604	7/16	15.466	13.9408	7/8	61.862	27.8816
1/2	1.7671	4.71239	1/2	15.904	14.1372	9	63.617	28.2743
9/16	1.9175	4.90874	9/16	16.349	14.3335	1/8	65.397	28.6670
5/8	2.0739	5.10509	5/8	16.800	14.5299	1/4	67.201	29.0597
11/16	2.2365	5.30144	11/16	17.257	14.7262	3/8	69.029	29.4524
3/4	2.4053	5.49779	3/4	17.721	14.9226	1/2	70.882	29.8451
13/16	2.5802	5.69414	13/16	18.190	15.1189	5/8	72.760	30.2378
7/8	2.7612	5.89049	7/8	18.665	15.3153	3/4	74.662	30.6305
15/16	2.9483	6.08684	15/16	19.147	15.5116	7/8	76.589	31.0232

Areas and Circumferences of Circles from 1 to 100

Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.
10	78.540	31.4159	16	201.06	50.2655	22	380.13	69.1150
1/8	80.516	31.8086	1/8	204.22	50.6582	1/8	384.46	69.5077
1/4	82.516	32.2013	1/4	207.39	51.0509	1/4	388.82	69.9004
3/8	84.541	32.5940	3/8	210.60	51.4436	3/8	393.20	70.2931
1/2	86.590	32.9867	1/2	213.82	51.8363	1/2	397.61	70.6858
5/8	88.664	33.3794	5/8	217.08	52.2290	5/8	402.04	71.0785
3/4	90.763	33.7721	3/4	220.35	52.6217	3/4	406.49	71.4712
7/8	92.886	34.1648	7/8	223.65	53.0144	7/8	410.97	71.8639
11	95.033	34.5575	17	226.98	53.4071	23	415.48	72.2566
1/8	97.205	34.9502	1/8	230.33	53.7998	1/8	420.00	72.6493
1/4	99.402	35.3429	1/4	233.71	54.1925	1/4	424.56	73.0420
3/8	101.62	35.7356	3/8	237.10	54.5852	3/8	429.13	73.4347
1/2	103.87	36.1283	1/2	240.53	54.9779	1/2	433.74	73.8274
5/8	106.14	36.5210	5/8	243.98	55.3706	5/8	438.36	74.2201
3/4	108.43	36.9137	3/4	247.45	55.7633	3/4	443.01	74.6128
7/8	110.75	37.3064	7/8	250.95	56.1560	7/8	447.69	75.0055
12	113.10	37.6991	18	254.47	56.5487	24	452.39	75.3982
1/8	115.47	38.0918	1/8	258.02	56.9414	1/8	457.11	75.7909
1/4	117.86	38.4845	1/4	261.59	57.3341	1/4	461.86	76.1836
3/8	120.28	38.8772	3/8	265.18	57.7268	3/8	466.64	76.5765
1/2	122.72	39.2699	1/2	268.80	58.1195	1/2	471.44	76.9690
5/8	125.19	39.6626	5/8	272.45	58.5122	5/8	476.26	77.3617
3/4	127.68	40.0553	3/4	276.12	58.9049	3/4	481.11	77.7544
7/8	130.19	40.4480	7/8	279.81	59.2976	7/8	485.98	78.1471
13	132.73	40.8407	19	283.53	59.6903	25	490.87	78.5398
1/8	135.30	41.2334	1/8	287.27	60.0830	1/8	495.79	78.9325
1/4	137.89	41.6261	1/4	291.04	60.4757	1/4	500.74	79.3252
3/8	140.50	42.0188	3/8	294.83	60.8684	3/8	505.71	79.7179
1/2	143.14	42.4115	1/2	298.65	61.2611	1/2	510.71	80.1105
5/8	145.80	42.8042	5/8	302.49	61.6538	5/8	515.72	80.5033
3/4	148.49	43.1969	3/4	306.35	62.0465	3/4	520.77	80.8960
7/8	151.20	43.5896	7/8	310.24	62.4392	7/8	525.84	81.2887
14	153.94	43.9823	20	314.16	62.8319	26	530.93	81.6814
1/8	156.70	44.3750	1/8	318.10	63.2246	1/8	536.05	82.0741
1/4	159.48	44.7677	1/4	322.06	63.6173	1/4	541.19	82.4668
3/8	162.30	45.1604	3/8	326.05	64.0100	3/8	546.35	82.8595
1/2	165.13	45.5531	1/2	330.06	64.4026	1/2	551.55	83.2522
5/8	167.99	45.9458	5/8	334.10	64.7953	5/8	556.76	83.6449
3/4	170.87	46.3385	3/4	338.16	65.1880	3/4	562.00	84.0376
7/8	173.78	46.7312	7/8	342.25	65.5807	7/8	567.27	84.4303
15	176.71	47.1239	21	346.36	65.9734	27	572.56	84.8230
1/8	179.67	47.5166	1/8	350.50	66.3661	1/8	577.87	85.2157
1/4	182.65	47.9093	1/4	354.66	66.7588	1/4	583.21	85.6084
3/8	185.66	48.3020	3/8	358.84	67.1515	3/8	588.57	86.0011
1/2	188.69	48.6947	1/2	363.05	67.5442	1/2	593.96	86.3938
5/8	191.75	49.0874	5/8	367.28	67.9369	5/8	599.37	86.7865
3/4	194.83	49.4801	3/4	371.54	68.3296	3/4	604.81	87.1792
7/8	197.93	49.8728	7/8	375.83	68.7223	7/8	610.27	87.5719

Areas and Circumferences of Circles from 1 to 100

Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.
28	615.75	87.9646	34	907.92	106.814	40	1256.6	125.664
⅛	621.26	88.3573	⅛	914.61	107.207	⅛	1264.5	126.056
¼	626.80	88.7500	¼	921.32	107.600	¼	1272.4	126.449
⅜	632.36	89.1427	⅜	928.06	107.992	⅜	1280.3	126.842
½	637.94	89.5354	½	934.82	108.385	½	1288.2	127.235
⅝	643.55	89.9281	⅝	941.61	108.788	⅝	1296.2	127.627
¾	649.18	90.3208	¾	948.42	109.170	¾	1304.2	128.020
⅞	656.84	90.7135	⅞	955.25	109.563	⅞	1312.2	128.413
29	660.52	91.1062	35	962.11	109.956	41	1320.3	128.805
⅛	666.23	91.4989	⅛	969.00	110.348	⅛	1328.3	129.198
¼	671.96	91.8916	¼	975.91	110.741	¼	1336.4	129.591
⅜	677.71	92.2843	⅜	982.84	111.134	⅜	1344.5	129.993
½	683.49	92.6770	½	989.80	111.527	½	1352.7	130.376
⅝	689.30	93.0697	⅝	996.78	111.919	⅝	1360.8	130.769
¾	695.13	93.4624	¾	1003.8	112.312	¾	1369.0	131.161
⅞	700.98	93.8551	⅞	1010.8	112.705	⅞	1377.2	131.554
30	706.86	94.2478	36	1017.9	113.097	42	1385.4	131.947
⅛	712.76	94.6405	⅛	1025.0	113.490	⅛	1393.7	132.340
¼	718.69	95.0332	¼	1032.1	113.883	¼	1402.0	132.732
⅜	724.64	95.4259	⅜	1039.2	114.275	⅜	1410.3	133.125
½	730.62	95.8186	½	1046.3	114.668	½	1418.6	133.518
⅝	736.62	96.2113	⅝	1053.5	115.061	⅝	1427.0	133.910
¾	742.64	96.6040	¾	1060.7	115.454	¾	1435.4	134.303
⅞	748.69	96.9967	⅞	1068.0	115.846	⅞	1443.8	134.696
31	754.77	97.3894	37	1075.2	116.239	43	1452.2	135.088
⅛	760.87	97.7821	⅛	1082.5	116.632	⅛	1460.7	135.481
¼	766.99	98.1748	¼	1089.8	117.024	¼	1469.1	135.874
⅜	773.14	98.5675	⅜	1097.1	117.417	⅜	1477.6	136.267
½	779.31	98.9602	½	1104.5	117.810	½	1486.2	136.659
⅝	785.51	99.3529	⅝	1111.8	118.202	⅝	1494.7	137.052
¾	791.73	99.7456	¾	1119.2	118.596	¾	1503.3	137.445
⅞	797.98	100.138	⅞	1126.7	118.988	⅞	1511.9	137.837
32	804.25	100.531	38	1134.1	119.381	44	1520.5	138.230
⅛	810.54	100.924	⅛	1141.6	119.773	⅛	1529.2	138.623
¼	816.86	101.316	¼	1149.1	120.166	¼	1537.9	139.015
⅜	823.21	101.709	⅜	1156.6	120.559	⅜	1546.6	139.408
½	829.58	102.102	½	1164.2	120.951	½	1555.3	139.801
⅝	835.97	102.494	⅝	1171.7	121.344	⅝	1564.0	140.194
¾	842.39	102.887	¾	1179.3	121.737	¾	1572.8	140.586
⅞	848.83	103.280	⅞	1186.9	122.129	⅞	1581.6	140.979
33	855.30	103.673	39	1194.6	122.522	45	1590.4	141.372
⅛	861.79	104.065	⅛	1202.3	122.915	⅛	1599.3	141.764
¼	868.31	104.458	¼	1210.0	123.308	¼	1608.2	142.157
⅜	874.85	104.851	⅜	1217.7	123.700	⅜	1617.0	142.550
½	881.41	105.243	½	1225.4	124.093	½	1626.0	142.942
⅝	888.00	105.636	⅝	1233.2	124.486	⅝	1634.9	143.335
¾	894.62	106.029	¾	1241.0	124.878	¾	1643.9	143.728
⅞	901.26	106.421	⅞	1248.8	125.271	⅞	1652.9	144.121

Areas and Circumferences of Circles from 1 to 100

Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.
46	1661.9	144.513	52	2123.7	163.363	58	2642.1	182.212
⅛	1670.9	144.906	⅛	2133.9	163.750	⅛	2653.5	182.605
¼	1680.0	145.299	¼	2144.2	164.148	¼	2664.9	182.998
⅜	1689.1	145.691	⅜	2154.5	164.541	⅜	2676.4	183.390
½	1698.2	146.084	½	2164.8	164.934	½	2687.8	183.783
⅝	1707.4	146.477	⅝	2175.1	165.326	⅝	2699.3	184.176
¾	1716.5	146.869	¾	2185.4	165.719	¾	2710.9	184.569
⅞	1725.7	147.262	⅞	2195.8	166.112	⅞	2722.4	184.961
47	1734.9	147.655	53	2206.2	166.504	59	2734.0	185.354
⅛	1744.2	148.048	⅛	2216.6	166.897	⅛	2745.6	185.747
¼	1753.5	148.440	¼	2227.0	167.290	¼	2757.2	186.139
⅜	1762.7	148.833	⅜	2237.5	167.683	⅜	2768.8	186.532
½	1772.1	149.226	½	2248.0	168.075	½	2780.5	186.925
⅝	1781.4	149.618	⅝	2258.5	168.468	⅝	2792.2	187.317
¾	1790.8	150.011	¾	2269.1	168.861	¾	2803.9	187.710
⅞	1800.1	150.404	⅞	2279.6	169.253	⅞	2815.7	188.103
48	1809.6	150.796	54	2290.2	169.646	60	2827.4	188.496
⅛	1819.0	151.189	⅛	2300.8	170.039	⅛	2839.2	188.888
¼	1828.5	151.582	¼	2311.5	170.431	¼	2851.0	189.281
⅜	1837 9	151.975	⅜	2322.1	170.824	⅜	2862.9	189.674
½	1847.5	152.367	½	2332 8	171.217	½	2874.8	190.066
⅝	1857.0	152.760	⅝	2343.5	171.609	⅝	2886.6	100.459
¾	1866.5	153.153	¾	2354.3	172.002	¾	2898.6	190.852
⅞	1876.1	153.544	⅞	2365.0	172.395	⅞	2910.5	191.244
49	1885.7	153.938	55	2375.8	172.788	61	2922.5	191.637
⅛	1895.4	154.331	⅛	2386.6	173.180	⅛	2934.5	192.030
¼	1905.0	154.723	¼	2397.5	173.573	¼	2946.5	192.423
⅜	1914.7	155.116	⅜	2408.3	173.966	⅜	2958.5	192.815
½	1924.2	155.509	½	2419.2	174.358	½	2970.6	193.208
⅝	1934.2	155.904	⅝	2430.1	174.751	⅝	2982.7	193.601
¾	1943.9	156.294	¾	2441.1	175.144	¾	2994.8	193.993
⅞	1953.7	156.687	⅞	2452.0	175.536	⅞	3006.9	194.386
50	1963.5	157.080	56	2463.0	175.929	62	3019.1	194.779
⅛	1973.3	157.472	⅛	2474.0	176.322	⅛	3031.3	195.171
¼	1983.2	157.865	¼	2485.0	176.715	¼	3043.5	195.564
⅜	1993.1	158.258	⅜	2496.1	177.107	⅜	3055.7	195.957
½	2003.0	158.650	½	2507.2	177.500	½	3068.0	196.350
⅝	2012.9	159.043	⅝	2518.3	177.893	⅝	3080.3	196.742
¾	2022.8	159.436	¾	2529.4	178.285	¾	3092.6	197.135
⅞	2032.8	159.829	⅞	2540.6	178.678	⅞	3104.9	197.528
51	2042.8	160.221	57	2551.8	179.071	63	3117.2	197.920
⅛	2052.8	160.614	⅛	2563.0	179.463	⅛	3129.6	198.313
¼	2062.9	161.007	¼	2574.2	179.856	¼	3142.0	198.706
⅜	2073.0	161.399	⅜	2585.4	180.249	⅜	3154.5	199.098
½	2083.1	161.792	½	2596.7	180.642	½	3166.9	199.491
⅝	2093.2	162.185	⅝	2608.0	181.034	⅝	3179.4	199.884
¾	2103.3	162.577	¾	2619.4	181.427	¾	3191.9	200.277
⅞	2113.5	162.970	⅞	2630.7	181.820	⅞	3204.4	200.669

Areas and Circumferences of Circles from 1 to 100

Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.
64	3217.0	201.062	70	3848.5	219.911	76	4536.5	238.761
1/8	3229.6	201.455	1/8	3862.2	220.304	1/8	4551.4	239.154
1/4	3242.2	201.847	1/4	3876.0	220.697	1/4	4566.4	239.546
3/8	3254.8	202.240	3/8	3889.8	221.090	3/8	4581.3	239.939
1/2	3267.5	202.633	1/2	3903.6	221.482	1/2	4596.3	240 332
5/8	3280.1	203.025	5/8	3917.5	221.875	5/8	4611.4	240.725
3/4	3292.8	203.418	3/4	3931.4	222.268	3/4	4626.4	241.117
7/8	3305.6	203.811	7/8	3945.3	222.660	7/8	4641.5	241.510
65	3318.3	204.204	71	3959.2	223.053	77	4656.6	241.903
1/8	3331.1	204.596	1/8	3973.1	223.446	1/8	4671.8	242.295
1/4	3343.9	204.989	1/4	3987.1	223.838	1/4	4686.9	242.688
3/8	3356.7	205.382	3/8	4001.1	224.231	3/8	4702.1	243.081
1/2	3369.6	205.774	1/2	4015.2	224.624	1/2	4717.3	243.473
5/8	3382.4	206.167	5/8	4029.2	225.017	5/8	4732.5	243.866
3/4	3395.3	206.560	3/4	4043.3	225.409	3/4	4747.8	244.259
7/8	3408.2	206.952	7/8	4057.4	225.802	7/8	4763.1	244.652
66	3421.2	207.345	72	4071.5	226.195	78	4778.4	245.044
1/8	3434.3	207.738	1/8	4085.7	226.587	1/8	4793.7	245.437
1/4	3447.2	208.131	1/4	4099.8	226.930	1/4	4809.0	245.830
3/8	3460.2	208.523	3/8	4114.0	227.373	3/8	4824.4	246.222
1/2	3473.2	208.916	1/2	4128.2	227.765	1/2	4839.8	246.615
5/8	3486.3	209.309	5/8	4142.5	228.158	5/8	4855.2	247.008
3/4	3499.4	209.701	3/4	4156.8	228.551	3/4	4870.7	247.400
7/8	3512.5	210.094	7/8	4171.1	228.944	7/8	4886.2	247.793
67	3525.7	210.487	73	4185.4	229.336	79	4901.7	248.186
1/8	3538.8	210.879	1/8	4199.7	229.729	1/8	4917.2	248.579
1/4	3552.0	211.272	1/4	4214.1	230.122	1/4	4932.7	248.971
3/8	3565.2	211.665	3/8	4228.5	230.514	3/8	4948.3	249.364
1/2	3578.5	212.058	1/2	4242.9	230.907	1/2	4963.9	249.757
5/8	3591.7	212.450	5/8	4257.4	231.300	5/8	4979.5	250.149
3/4	3605.0	212.843	3/4	4271.8	231.692	3/4	4995.2	250.542
7/8	3618.3	213.236	7/8	4286.3	232.085	7/8	5010.9	250.935
68	3631.7	213.628	74	4300.8	232.478	80	5026.5	251.327
1/8	3645.0	214.021	1/8	4315.4	232.871	1/8	5042.3	251.720
1/4	3658.4	214.414	1/4	4329.9	233.263	1/4	5058.0	252.113
3/8	3671.8	214.806	3/8	4344.5	233.656	3/8	5073.8	252.506
1/2	3685.3	215.199	1/2	4359.2	234.049	1/2	5089.6	252.898
5/8	3698.7	215.592	5/8	4373.8	234.441	5/8	5105.4	253.291
3/4	3712.2	215.984	3/4	4388.5	234.834	3/4	5121.2	253.684
7/8	3725.7	216.337	7/8	4403.1	235.227	7/8	5137.1	254.076
69	3739.3	216.770	75	4417.9	235.619	81	5153.0	254.469
1/8	3752.8	217.163	1/8	4432.6	236.012	1/8	5168.9	254.862
1/4	3766.4	217.555	1/4	4447.4	236.405	1/4	5184.9	255.254
3/8	3780.0	217.948	3/8	4462.2	236.798	3/8	5200.8	255.647
1/2	3793.7	218.341	1/2	4477.0	237.190	1/2	5216.8	256.040
5/8	3807.3	218.733	5/8	4491.8	237.583	5/8	5232.8	256.433
3/4	3821.0	219.126	3/4	4506.7	237.976	3/4	5248.9	256.825
7/8	3834.7	219.519	7/8	4521.5	238.368	7/8	5264.9	257.218

AREAS AND CIRCUMFERENCES OF CIRCLES FROM 1 TO 100

Dia.	Area	Circum.	Dia.	Area	Circum.	Dia.	Area	Circum.
82	5281.0	257.611	88	6082.1	276.460	94	6939.8	295.310
1/8	5297.1	258.003	1/8	6099.4	276.853	1/8	6958.2	295.702
1/4	5313.3	258.396	1/4	6256.7	277.846	1/4	6976.7	296.095
3/8	5329.4	258.789	3/8	6134.1	277.638	3/8	6995.3	296.488
1/2	5345.6	259.181	1/2	6151.4	278.031	1/2	7013.8	296.881
5/8	5361.8	259.574	5/8	6168.8	278.424	5/8	7032.4	297.273
3/4	5378.1	259.967	3/4	6186.2	278.816	3/4	7051.0	297.666
7/8	5394.3	260.359	7/8	6203.7	279.209	7/8	7069.6	298.059
83	5410.6	260.752	89	6221.1	279.602	95	7088.2	298.451
1/8	5426.9	261.145	1/8	6238.6	279.994	1/8	7106.9	298.844
1/4	5443.3	261.538	1/4	6256.1	280.387	1/4	7125.6	299.237
3/8	5459.6	261.930	3/8	6273.7	280.780	3/8	7144.3	299.629
1/2	5476.0	262.323	1/2	6291.2	281.173	1/2	7163.0	300.022
5/8	5492.4	262.716	5/8	6308.8	281.565	5/8	7181.8	300.415
3/4	5508.8	263.103	3/4	6326.4	281.958	3/4	7200.6	300.807
7/8	5525.3	263.501	7/8	6344.1	282.351	7/8	7219.4	301.200
84	5541.8	263.894	90	6361.7	282.743	96	7238.2	301.593
1/8	5558.3	264.286	1/8	6379.4	283.136	1/8	7257.1	301.986
1/4	5574.8	264.679	1/4	6397.1	283.529	1/4	7276.0	302.378
3/8	5591.4	265.072	3/8	6414.9	283.921	3/8	7294.9	302.771
1/2	5607.9	265.465	1/2	6432.6	284.314	1/2	7313.8	303.164
5/8	5624.5	265.857	5/8	6450.4	284.707	5/8	7332.8	303.556
3/4	5641.2	266.250	3/4	6468.2	285.100	3/4	7351.8	303.949
7/8	5657.8	266.643	7/8	6486.0	285.492	7/8	7370.8	304.342
85	5674.5	267.035	91	6503.9	285.885	97	7389.8	304.734
1/8	5691.2	267.428	1/8	6521.8	286.278	1/8	7408.9	305.127
1/4	5707.9	267.821	1/4	6539.7	286.670	1/4	7428.0	305.520
3/8	5724.7	268.213	3/8	6557.6	287.063	3/8	7447.1	305.913
1/2	5741.5	268.606	1/2	6575.5	287.456	1/2	7466.2	306.305
5/8	5758.3	268.999	5/8	6593.5	287.848	5/8	7485.3	306.698
3/4	5775.1	269.392	3/4	6611.5	288.241	3/4	7504.5	307.091
7/8	5791.9	269.784	7/8	6629.6	288.634	7/8	7523.7	307.483
86	5808.8	270.177	92	6647.6	289.027	98	7543.0	307.876
1/8	5825.7	270.570	1/8	6665.7	289.419	1/8	7562.2	308.269
1/4	5842.6	270.962	1/4	6683.8	289.812	1/4	7581.5	308.661
3/8	5859.6	271.355	3/8	6701.9	290.205	3/8	7600.8	309.064
1/2	5876.5	271.748	1/2	6720.1	290.597	1/2	7620.1	309.447
5/8	5893.5	272.140	5/8	6738.2	290.990	5/8	7639.5	309.840
3/4	5910.6	272.533	3/4	6756.4	291.383	3/4	7658.9	310.232
7/8	5927.6	272.926	7/8	6774.7	291.775	7/8	7678.3	310.625
87	5944.7	273.319	93	6792.9	292.168	99	7697.7	311.018
1/8	5961.8	273.711	1/8	6811.2	292.561	1/8	7717.1	311.410
1/4	5978.9	274.104	1/4	6829.5	292.954	1/4	7736.6	311.803
3/8	5996.0	274.497	3/8	6847.8	293.346	3/8	7756.1	312.196
1/2	6013.2	274.889	1/2	6866.1	293.739	1/2	7775.6	312.588
5/8	6030.4	275.282	5/8	6884.5	294.132	5/8	7795.2	312.981
3/4	6047.6	275.675	3/4	6902.9	294.524	3/4	7814.8	313.374
7/8	6064.9	276.067	7/8	6921.3	294.917	7/8	7834.4	313.767

Areas and Circumferences of Circles from 100 to 1000

Diam.	Area.	Circum.	Diam.	Area	Circum.	Diam.	Area	Circum.
100	7853.98	314.16	150	17671.46	471.24	200	31415.93	628.32
101	8011.85	317.30	151	17907.86	474.38	201	31730.87	631.46
102	8171.28	320.44	152	18145.84	477.52	202	32047.39	634.60
103	8332.29	323.58	153	18385.39	480.66	203	32365.47	637.74
104	8494.87	326.73	154	18626.50	483.81	204	32685.13	640.88
105	8659.01	329.87	155	18869.19	486.95	205	33006.36	644.03
106	8824.73	333.01	156	19113.45	490.09	206	33329.16	647.17
107	8992.02	336.15	157	19359.28	493.23	207	33653.53	650.31
108	9160.88	339.29	158	19606.68	496.37	208	33979.47	653.45
109	9331.32	342.43	159	19855.65	499.51	209	34306.98	656.59
110	9503.32	345.58	160	20106.19	502.65	210	34636.06	659.73
111	9676.89	348.72	161	20358.31	505.80	211	34966.71	662.88
112	9852.03	351.86	162	20611.99	508.94	212	35298.94	666.02
113	10028.75	355.00	163	20867.24	512.08	213	35632.73	669.16
114	10207.03	358.14	164	21124.07	515.22	214	35968.09	672.30
115	10386.89	361.28	165	21382.46	518.36	215	36305.03	675.44
116	10568.32	364.42	166	21642.43	521.50	216	36643.54	678.58
117	10751.32	367.57	167	21903.97	524.65	217	36983.61	681.73
118	10935.88	370.71	168	22167.08	527.79	218	37325.26	684.87
119	11122.02	373.85	169	22431.76	530.93	219	37668.48	688.01
120	11309.73	376.99	170	22698.01	534.07	220	38013.27	691.15
121	11499.01	380.13	171	22965.83	537.21	221	38359.63	694.29
122	11689.87	383.27	172	23235.22	540.35	222	38707.56	697.43
123	11882.29	386.42	173	23506.18	543.50	223	39057.07	700.58
124	12076.28	389.56	174	23778.71	546.64	224	39408.14	703.72
125	12271.85	392.70	175	24052.82	549.78	225	39760.78	706.86
126	12468.98	395.84	176	24328.49	552.92	226	40115.00	710.00
127	12667.69	398.98	177	24605.74	556.06	227	40470.78	713.14
128	12867.96	402.12	178	24884.56	559.20	228	40828.14	716.28
129	13069.81	405.27	179	25164.94	562.35	229	41187.07	719.42
130	13273.23	408.41	180	25446.90	565.49	230	41547.56	722.57
131	13478.22	411.55	181	25730.43	568.63	231	41909.63	725.71
132	13684.78	414.69	182	26015.53	571.77	232	42273.27	728.85
133	13892.91	417.83	183	26302.20	574.91	233	42638.48	731.99
134	14102.61	420.97	184	26590.44	578.05	234	43005.26	735.13
135	14313.88	424.12	185	26880.25	581.19	235	43373.61	738.27
136	14526.72	427.26	186	27171.63	584.34	236	43743.54	741.42
137	14741.14	430.40	187	27464.59	587.48	237	44115.03	744.56
138	14957.12	433.54	188	27759.11	590.62	238	44488.09	747.70
139	15174.68	436.68	189	28055.21	593.76	239	44862.73	750.84
140	15393.80	439.82	190	28352.87	596.00	240	45238.93	753.98
141	15614.50	442.96	191	28652.11	600.04	241	45616.71	757.12
142	15836.77	446.11	192	28952.92	603.19	242	45996.06	760.27
143	16060.61	449.25	193	29255.30	606.33	243	46376.98	763.41
144	16286.02	452.39	194	29559.25	609.47	244	46759.47	766.55
145	16513.00	455.53	195	29864.77	612.61	245	47143.52	769.69
146	16741.55	458.67	196	30171.86	615.75	246	47529.16	772.83
147	16971.67	461.81	197	30480.52	618.89	247	47916.36	775.97
148	17203.36	464.96	198	30790.75	622.04	248	48305.13	779.11
149	17436.62	468.10	199	31102.55	625.18	249	48695.47	782.26

Areas and Circumferences of Circles from 100 to 1000

Diam.	Area	Circum.	Diam.	Area	Circum.	Diam.	Area	Circum.
250	49087.39	785.40	300	70685.83	942.48	350	96211.28	1099.56
251	49480.87	788.54	301	71157.86	945.62	351	96761.84	1102.70
252	49875.02	791.68	302	71631.45	948.76	352	97313.97	1105.84
253	50272.55	794.82	303	72106.62	951.90	353	97867.68	1108.98
254	50670.75	797.96	304	72583.36	955.04	354	98422.96	1112.12
255	51070.52	801.11	305	73061.66	958.19	355	98979.80	1115.27
256	51471.85	804.25	306	73541.54	961.33	356	99538.22	1118.41
257	51874.76	807.39	307	74022.99	964.47	357	100098.21	1121.55
258	52279.24	810.53	308	74506.01	967.61	358	100659.77	1124.69
259	52685.29	813.67	309	74990.60	970.75	359	101222.90	1127.83
260	53092.92	816.81	310	75476.76	973.89	360	101787.60	1130.97
261	53502.11	819.96	311	75964.50	977.04	361	102353.87	1134.11
262	53912.87	823.10	312	76453.80	980.18	362	102921.72	1137.26
263	54325.21	826.24	313	76944.67	983.32	363	103491.13	1140.40
264	54739.11	829.38	314	77437.12	986.46	364	104062.12	1143.54
265	55154.59	832.52	315	77931.13	989.60	365	104634.67	1146.68
266	55571.63	835.66	316	78426.72	992.74	366	105208.80	1149.82
267	55990.25	838.81	317	78923.88	995.88	367	105784.49	1152.96
268	56410.44	841.95	318	79422.60	999.03	368	106361.76	1156.11
269	56832.20	845.09	319	79922.90	1002.17	369	106940.60	1159.25
270	57255.53	848.23	320	80424.77	1005.31	370	107521.01	1162.39
271	57680.43	851.37	321	80928.21	1008.45	371	108102.99	1165.53
272	58106.90	854.51	322	81433.22	1011.59	372	108686.54	1168.67
273	58534.94	857.65	323	81939.80	1014.73	373	109271.66	1171.81
274	58964.55	860.80	324	82447.96	1017.88	374	109858.35	1174.96
275	59395.74	863.94	325	82957.68	1021.02	375	110446.62	1178.10
276	59828.49	867.08	326	83468.98	1024.16	376	111036.45	1181.24
277	60262.82	870.22	327	83981.84	1027.30	377	111627.86	1184.38
278	60698.71	873.36	328	84496.28	1030.44	378	112220.83	1187.52
279	61136.18	876.50	329	85012.28	1033.58	379	112815.38	1190.66
280	61575.22	879.65	330	85529.86	1036.73	380	113411.49	1193.81
281	62015.82	882.79	331	86049.01	1039.87	381	114009.18	1196.95
282	62458.00	885.93	332	86569.73	1043.01	382	114608.44	1200.09
283	62901.75	889.07	333	87092.02	1046.15	383	115209.27	1203.23
284	63347.07	892.21	334	87615.88	1049.29	384	115811.67	1206.37
285	63793.97	895.35	335	88141.31	1052.43	385	116415.64	1209.51
286	64242.43	898.50	336	88668.31	1055.58	386	117021.18	1212.65
287	64692.46	901.64	337	89196.88	1058.72	387	117628.30	1215.80
288	65144.07	904.78	338	89727.03	1061.86	388	118236.98	1218.94
289	65597.24	907.92	339	90258.74	1065.00	389	118847.24	1222.08
290	66051.99	911.06	340	90792.03	1068.14	390	119459.06	1225.22
291	66508.30	914.20	341	91326.88	1071.28	391	120072.46	1228.36
292	66966.19	917.35	342	91863.31	1074.42	392	120687.42	1231.50
293	67425.65	920.49	343	92401.31	1077.57	393	121303.96	1234.65
294	67886.68	923.63	344	92940.88	1080.71	394	121922.07	1237.79
295	68349.28	926.77	345	93482.02	1083.85	395	122541.75	1240.93
296	68813.45	929.91	346	94024.73	1086.99	396	123163.00	1244.07
297	69279.19	933.05	347	94569.01	1090.13	397	123785.82	1247.21
298	69746.50	936.19	348	95114.86	1093.27	398	124410.21	1250.35
299	70215.38	939.34	349	95662.28	1096.42	399	125036.17	1253.50

Areas and Circumferences of Circles from 100 to 1000

Diam.	Area	Circum.	Diam.	Area	Circum.	Diam.	Area	Circum.
400	125663.71	1256.64	450	159043.13	1413.72	500	196349.54	1570.80
401	126292.81	1250.78	451	159750.77	1416.86	501	197135.72	1573.94
402	126923.48	1262.92	452	160459.09	1420.00	502	197923.48	1577.08
403	127555.73	1266.06	453	161170.77	1423.14	503	198712.80	1580.22
404	128189.55	1269.20	454	161883.13	1426.28	504	190503.70	1583.36
405	128824.93	1272.35	455	162597.05	1429.42	505	200296.17	1586.50
406	129461.89	1275.49	456	163312.55	1432.57	506	201090.20	1589.05
407	130100.42	1278.63	457	164029.62	1435.71	507	201885.81	1592.79
408	130740.52	1281.77	458	161748.26	1438.85	508	202682.99	1595.93
409	131382.19	1284.91	459	165468.47	1441.99	509	203481.74	1599.07
410	132025.43	1288.05	460	166190.25	1445.13	510	204282.06	1602.21
411	132670.24	1291.19	461	166913.60	1448.27	511	205083.95	1605.35
412	133316.63	1294.34	462	167638.53	1451.42	512	205887.42	1608.50
413	133964.58	1297.48	463	168365.02	1454.56	513	206692.45	1611.64
414	134614.10	1300.62	464	169093.08	1457.70	514	207499.05	1614.78
415	135265.20	1303.76	465	169822.72	1460.84	515	208307.23	1617.92
416	135917.86	1306.90	466	170553.92	1463.98	516	209116.97	1621.06
417	136572.10	1310.04	467	171286.70	1467.12	517	209928.29	1624.20
418	137227.91	1313.19	468	172021.05	1470.27	518	210741.18	1627.34
419	137885.29	1316.33	469	172756.97	1473.41	519	211555.63	1630.49
420	138544.24	1319.47	470	173494.45	1476.55	520	212371.66	1633.63
421	139204.76	1322.61	471	174233.51	1479.69	521	213189.26	1636.77
422	139866.85	1325.75	472	174974.14	1482.83	522	214008.43	1639.91
423	140530.51	1328.89	473	175716.35	1485.97	523	214829.17	1643.05
424	141195.74	1332.04	474	176460.12	1489.11	524	215651.49	1646.19
425	141862.54	1335.18	475	177205.46	1492.26	525	216475.37	1649.34
426	142530.92	1338.32	476	177952.37	1495.40	526	217300.82	1652.48
427	143200.86	1341.46	477	178700.86	1498.54	527	218127.85	1655.62
428	143872.38	1344.60	478	179450.91	1501.68	528	218956.43	1658.76
429	144545.46	1347.74	479	180202.54	1504.82	529	219786.61	1661.90
430	145220.12	1350.88	480	180955.74	1507.96	530	220618.34	1665.04
431	145896.35	1354.03	481	181710.50	1511.11	531	221451.65	1668.19
432	146574.15	1357.17	482	182466.84	1514.25	532	222286.53	1671.33
433	147253.52	1360.31	483	183224.75	1517.39	533	223122.98	1674.47
434	147934.46	1363.45	484	183984.23	1520.53	534	223961.00	1677.61
435	148616.97	1366.59	485	184745.28	1523.67	535	224800.59	1680.75
436	149301.05	1369.73	486	185507.90	1526.81	536	225641.75	1683.89
437	149986.70	1372.88	487	186272.10	1529.96	537	226484.48	1687.04
438	150673.93	1376.02	488	187037.86	1533.10	538	227328.79	1690.18
439	151362.72	1379.16	489	187805.19	1536.24	539	228174.66	1693.32
440	152053.08	1382.30	490	188574.10	1539.38	540	229022.10	1696.46
441	152745.02	1385.44	491	189344.57	1542.52	541	229871.12	1699.60
442	153438.53	1388.58	492	190116.62	1545.66	542	230721.71	1702.74
443	154133.60	1391.73	493	190890.24	1548.81	543	231573.86	1705.88
444	154830.25	1394.87	494	191665.43	1551.95	544	232427.59	1709.03
445	155528.47	1398.01	495	192442.18	1555.09	545	233282.89	1712.17
446	156228.26	1401.15	496	193220.51	1558.23	546	234139.76	1715.31
447	156929.62	1404.29	497	194000.41	1561.37	547	234998.20	1718.45
448	157632.55	1407.43	498	194781.89	1564.51	548	235858.21	1721.59
449	158337.06	1410.58	499	195564.93	1567.65	549	236719.79	1724.73

Areas and Circumferences of Circles from 100 to 1000

Diam.	Area	Circum.	Diam.	Area	Circum.	Diam.	Area	Circum.
550	237582.94	1727.88	600	282743.34	1884.96	650	331830.72	2042.04
551	238447.67	1731.02	601	283686.60	1888.10	651	332852.53	2045.18
552	239313.96	1734.16	602	284631.44	1891.24	652	333875.90	2048.32
553	240181.83	1737.30	603	285577.84	1894.38	653	334900.85	2051.46
554	241051.26	1740.44	604	286525.82	1897.52	654	335927.36	2054.60
555	241922.27	1743.58	605	287475.36	1900.66	655	336955.45	2057.74
556	242794.85	1746.73	606	288426.48	1903.81	656	337985.10	2060.88
557	243668.99	1749.87	607	289379.17	1906.95	657	339016.33	2064.03
558	244544.71	1753.01	608	290333.43	1910.09	658	340049.13	2067.17
559	245422.00	1756.15	609	291289.26	1913.23	659	341083.50	2070.31
560	246300.86	1759.29	610	292246.66	1916.37	660	342119.44	2073.45
561	247181.30	1762.43	611	293205.63	1919.51	661	343156.95	2076.59
562	248063.30	1765.58	612	294166.17	1922.65	662	344196.03	2079.73
563	248946.87	1768.72	613	295128.28	1925.80	663	345236.69	2082.88
564	249832.01	1771.86	614	296091.97	1928.94	664	346278.91	2086.02
565	250718.73	1775.00	615	297057.22	1932.08	665	347322.70	2089.16
566	251607.01	1778.14	616	298024.05	1935.22	666	348368.07	2092.30
567	252496.87	1781.28	617	298992.44	1938.36	667	349415.00	2095.44
568	253388.30	1784.42	618	299962.41	1941.50	668	350463.51	2098.58
569	254281.29	1787.57	619	300933.95	1944.65	669	351513.59	2101.73
570	255175.86	1790.71	620	301907.05	1947.79	670	352565.24	2104.87
571	256072.00	1793.85	621	302881.73	1950.93	671	353618.45	2108.01
572	256969.71	1796.99	622	303857.98	1954.07	672	354673.24	2111.15
573	257868.99	1800.13	623	304835.80	1957.21	673	355730.60	2114.29
574	258769.85	1803.27	624	305815.20	1960.35	674	356787.54	2117.43
575	259672.27	1806.42	625	306796.16	1963.50	675	357847.04	2120.58
576	260576.26	1809.56	626	307778.69	1966.64	676	358908.11	2123.72
577	261481.83	1812.70	627	308762.79	1969.78	677	359970.75	2126.86
578	262388.96	1815.84	628	309748.47	1972.92	678	361034.97	2130.00
579	263297.67	1818.98	629	310735.71	1976.06	679	362100.75	2133.14
580	264207.94	1822.12	630	311724.53	1979.20	680	363168.11	2136.28
581	265119.79	1825.27	631	312714.92	1982.35	681	364237.04	2139.42
582	266033.21	1828.41	632	313706.88	1985.49	682	365307.54	2142.57
583	266948.20	1831.55	633	314700.40	1988.63	683	366379.60	2145.71
584	267864.76	1834.69	634	315695.50	1991.77	684	367453.24	2148.85
585	268782.89	1837.83	635	316692.17	1994.91	685	368528.45	2151.99
586	269702.59	1840.97	636	317690.42	1998.05	686	369605.23	2155.13
587	270623.86	1844.11	637	318690.23	2001.19	687	370683.59	2158.27
588	271546.70	1847.26	638	319691.61	2004.34	688	371763.51	2161.42
589	272471.12	1850.40	639	320694.56	2007.48	689	372845.00	2164.56
590	273397.10	1853.54	640	321699.09	2010.62	690	373028.07	2167.70
591	274324.66	1856.68	641	322705.18	2013.76	691	375012.70	2170.84
592	275253.78	1859.82	642	323712.85	2016.90	692	376098.91	2173.98
593	276184.48	1862.96	643	324722.09	2020.04	693	377186.68	2177.12
594	277116.75	1866.11	644	325732.89	2023.19	694	378276.03	2180.27
595	278050.58	1869.25	645	326745.27	2026.33	695	379366.93	2183.41
596	278985.99	1872.39	646	327759.22	2029.47	696	380459.44	2186.55
597	279922.97	1875.53	647	328774.74	2032.61	697	381553.50	2189.69
598	280861.52	1878.67	648	329791.83	2035.75	698	382649.13	2192.83
599	281801.65	1881.81	649	330810.49	2038.89	699	383740.33	2195.97

Areas and Circumferences of Circles from 100 to 1000

Diam.	Area	Circum.	Diam.	Area	Circum.	Diam.	Area	Circum.
700	384845.10	2199.11	750	441786.47	2356.19	800	502654.82	2513.27
701	385945.44	2202.26	751	442965.35	2359.34	801	503912.25	2516.42
702	387047.36	2205.40	752	444145.80	2362.48	802	505171.24	2519.56
703	388150.84	2208.54	753	445327.83	2365.62	803	506431.80	2522.70
704	389255.90	2211.68	754	446511.42	2368.76	804	507693.94	2525.84
705	390362.52	2214.82	755	447696.59	2371.90	805	508957.64	2528.98
706	391470.72	2217.96	756	448883.32	2375 04	806	510222.92	2532.12
707	392580.49	2221.11	757	450071.63	2378.19	807	511489.77	2535.27
708	393691.82	2224.25	758	451261.51	2381.33	808	512758.19	2538.41
709	394804.73	2227.39	759	452452.96	2384.47	809	514028.18	2541.55
710	395919.21	2230.53	760	453645.98	2387.61	810	515299.74	2544.69
711	397035.26	2233.67	761	454840.57	2390.75	811	516572.87	2547.83
712	398152.89	2236.81	762	456036.73	2393.89	812	517847.57	2550.97
713	399272.08	2239.96	763	457234.46	2397.04	813	519123.84	2554.11
714	400392.84	2243.10	764	458433.77	2400.18	814	520401.68	2557.26
715	401515.18	2246.24	765	459634.64	2403.32	815	521681.10	2560.40
716	402639.08	2249.38	766	460837.08	2406.46	816	522962.08	2563.54
717	403764.56	2252.52	767	462041.10	2409.60	817	524244.63	2566.68
718	404891.60	2255.66	768	463246.69	2412.74	818	525528.76	2569.82
719	406020.22	2258.81	769	464453.84	2415.88	819	526814.46	2572.96
720	407150.41	2261.95	770	465662.57	2419.03	820	528101.73	2576.11
721	408282.17	2265.09	771	466872.87	2422.17	821	529390.56	2579.25
722	409415.50	2268.23	772	468084.74	2425.31	822	530680.97	2582.39
723	410550.40	2271.37	773	469298.18	2428.45	823	531972.95	2585.53
724	411686.87	2274.51	774	470513.19	2431.59	824	533266.50	2588.67
725	412824.91	2277.65	775	471729.77	2434.73	825	534561.62	2591.81
726	413964.52	2280.80	776	472947.92	2437.88	826	535858.32	2594.96
727	415105.71	2283.94	777	474167.65	2441.02	827	537156.58	2598.10
728	416248.46	2287.08	778	475388.94	2444.16	828	538456.41	2601.24
729	417392.79	2290.22	779	476611.81	2447.30	829	539757.82	2604.38
730	418538.68	2293.36	780	477836.24	2450.44	830	541060.79	2607.52
731	419686.15	2296.50	781	479062.25	2453.58	831	542365.34	2610.66
732	420835.19	2299.65	782	480289.83	2456.73	832	543671.46	2613.81
733	421985.79	2302.79	783	481518.97	2459.87	833	544979.15	2616.95
734	423137.97	2305.93	784	482749.69	2463.01	834	546288.40	2620.09
735	424291.72	2309.07	785	483981.98	2466.15	835	547599.23	2623.23
736	425447.04	2312.21	786	485215.84	2469.29	836	548911.63	2626.37
737	426603.94	2315.35	787	486451.28	2472.43	837	550225.61	2629.51
738	427762.40	2318.50	788	487688.28	2475.58	838	551541.15	2632.65
739	428922.43	2321.64	789	488926.85	2478.72	839	552858.26	2635.80
740	430084.03	2324.78	790	490166.99	2481.86	840	554176.94	2638.94
741	431247.21	2327.92	791	491408.71	2485.00	841	555497.20	2642.08
742	432411.95	2331.06	792	492651.99	2488.14	842	556819.02	2645.22
743	433578.27	2334.20	793	493896.85	2491.28	843	558142.42	2648.36
744	434746.16	2337.34	794	495143.28	2494.42	844	559467.39	2651.50
745	435915.62	2340.49	795	496391.27	2497.57	845	560793.92	2654.65
746	437086.64	2343.63	796	497640.84	2500.71	846	562122.03	2657.79
747	438259.24	2346.77	797	498891.98	2503.85	847	563451.71	2660.93
748	439433.41	2349.91	798	500144.69	2506.99	848	564782.96	2664.07
749	440609.16	2353.05	799	501398.97	2510.13	849	566115.78	2667.21

Areas and Circumferences of Circles from 100 to 1000

Diam.	Area	Circum.	Diam.	Area	Circum.	Diam.	Area	Circum.
850	567450.17	2670.35	900	636172.51	2827.43	950	708821.84	2984.51
851	568786.14	2673.50	901	637587.01	2830.58	951	710314.88	2987.65
852	570123.67	2676.64	902	639003.09	2833.72	952	711809.50	2990.80
853	571462.77	2679.78	903	640420.73	2836.86	953	713305.68	2993.94
854	572803.45	2682.92	904	641839.95	2840.00	954	714803.43	2997.08
855	574145.69	2686.06	905	643260.73	2843.14	955	716302.76	3000.22
856	575489.51	2689.20	906	644683.09	2846.28	956	717803.66	3003.36
857	576834.90	2692.34	907	646107.01	2849.42	957	719306.12	3006.50
858	578181.85	2695.49	908	647532.51	2852.57	958	720810.16	3009.65
859	579530.38	2698.03	909	648959.58	2855.71	959	722315.77	3012.79
860	580880.48	2701.77	910	650388.22	2858.85	960	723822.95	3015.03
861	582232.15	2704.91	911	651818.43	2861.99	961	725331.70	3019.07
862	583585.39	2708.05	912	653250.21	2865.13	962	726842.02	3022.21
863	584940.20	2711.19	913	654683.56	2868.27	963	728353.91	3025.35
864	586296.59	2714.34	914	656118.48	2871.42	964	729867.37	3028.50
865	587654.54	2717.48	915	657554.98	2874.56	965	731382.40	3031.64
866	589014.07	2720.62	916	658993.04	2877.70	966	732899.01	3034.78
867	590375.16	2723.76	917	660432.68	2880.84	967	734417.18	3037.92
868	591737.83	2726.90	918	661873.88	2883.98	968	735936.93	3041.06
869	593102.06	2730.04	919	663316.66	2887.12	969	737458.24	3044.20
870	594467.87	2733.19	920	664761.01	2890.27	970	738981.13	3047.34
871	595835.25	2736.33	921	666206.92	2893.41	971	740505.59	3050.49
872	597204.20	2739.47	922	667654.41	2896.55	972	742031.62	3053.63
873	598574.72	2742.61	923	669103.47	2899.69	973	743559.22	3056.77
874	599946.81	2745.75	924	670554.10	2902.83	974	745088.39	3059.91
875	601320.47	2748.89	925	672006.30	2905.97	975	746619.13	3063.05
876	602695.70	2752.04	926	673460.08	2909.11	976	748151.44	3066.19
877	604072.50	2755.18	927	674915.42	2912.26	977	749685.32	3069.34
878	605450.88	2758.32	928	676372.33	2915.40	978	751220.78	3072.48
879	606830.82	2761.46	929	677830.82	2918.54	979	752757.80	3075.62
880	608212.34	2764.60	930	679290.87	2921.68	980	754296.40	3078.76
881	609595.42	2767.74	931	680752.50	2924.82	981	755836.59	3081.90
882	610980.08	2770.88	932	682215.69	2927.96	982	757378.30	3085.04
883	612366.31	2774.03	933	683680.46	2931.11	983	758921.61	3088.19
884	613754.11	2777.17	934	685146.80	2934.25	984	760466.48	3091.33
885	615143.48	2780.31	935	686614.71	2937.39	985	762012.93	3094.47
886	616534.42	2783.45	936	688084.19	2940.53	986	763560.95	3097.61
887	617926.93	2786.59	937	689555.24	2943.67	987	765110.54	3100.75
888	619321.01	2789.73	938	691027.86	2946.81	988	766661.70	3103.89
889	620716.66	2792.88	939	692502.05	2949.96	989	768214.44	3107.04
890	622113.89	2796.02	940	693977.82	2953.10	990	769768.74	3110.18
891	623512.68	2799.16	941	695455.15	2956.24	991	771324.61	3113.32
892	624913.04	2802.30	942	696934.06	2959.38	992	772882.06	3116.46
893	626314.98	2805.44	943	698414.53	2962.52	993	774441.07	3119.60
894	627718.49	2808.58	944	699896.58	2965.66	994	776001.66	3122.74
895	629123.56	2811.73	945	701380.19	2968.81	995	777563.82	3125.88
896	630530.21	2814.87	946	702865.38	2971.95	996	779127.54	3129.03
897	631938.43	2818.01	947	704352.14	2975.09	997	780692.84	3132.17
898	633348.22	2821.15	948	705840.47	2978.23	998	782259.71	3135.31
899	634759.58	2824.29	949	707330.37	2981.37	999	783828.15	3138.45
						1000	785398.16	3141.59

Circumferences and Diameters of Circles

Circum.	Diameter	Circum.	Diameter	Circum.	Diameter	Circum.	Diameter
1	.3183	51	16.2338	101	32.1493	151	48.0648
2	.6366	52	16.5521	102	32.4676	152	48.3831
3	.9549	53	16.8704	103	32.7859	153	48.7014
4	1.2732	54	17.1887	104	33.1042	154	49.0197
5	1.5915	55	17.5070	105	33.4225	155	49.3380
6	1.9099	56	17.8254	106	33.7408	156	49.6563
7	2.2282	57	18.1437	107	34.0592	157	49.9747
8	2.5465	58	18.4620	108	34.3775	158	50.2930
9	2.8648	59	18.7803	109	34.6958	159	50.6113
10	3.1831	60	19.0986	110	35.0141	160	50.9296
11	3.5014	61	19.4169	111	35.3324	161	51.2479
12	3.8197	62	19.7352	112	35.6507	162	51.5662
13	4.1380	63	20.0535	113	35.9690	163	51.8845
14	4.4563	64	20.3718	114	36.2873	164	52.2028
15	4.7746	65	20.6901	115	36.6056	165	52.5211
16	5.0930	66	21.0085	116	36.9239	166	52.8394
17	5.4113	67	21.3268	117	37.2423	167	53.1578
18	5.7296	68	21.6451	118	37.5606	168	53.4761
19	6.0479	69	21.9634	119	37.8789	169	53.7944
20	6.3662	70	22.2817	120	38.1972	170	54.1127
21	6.6845	71	22.6000	121	38.5155	171	54.4310
22	7.0028	72	22.9183	122	38.8338	172	54.7493
23	7.3211	73	23.2366	123	39.1521	173	55.0676
24	7.6394	74	23.5549	124	39.4704	174	55.3859
25	7.9577	75	23.8732	125	39.7887	175	55.7042
26	8.2761	76	24.1916	126	40.1070	176	56.0225
27	8.5944	77	24.5099	127	40.4254	177	56.3408
28	8.9127	78	24.8282	128	40.7437	178	56.6592
29	9.2310	79	25.1465	129	41.0620	179	56.9775
30	9.5493	80	25.4648	130	41.3803	180	57.2958
31	9.8676	81	25.7831	131	41.6986	181	57.6141
32	10.1859	82	26.1014	132	42.0169	182	57.9324
33	10.5042	83	26.4197	133	42.3352	183	58.2507
34	10.8225	84	26.7380	134	42.6535	184	58.5690
35	11.1408	85	27.0563	135	42.9718	185	58.8873
36	11.4592	86	27.3747	136	43.2901	186	59.2056
37	11.7775	87	27.6930	137	43.6085	187	59.5239
38	12.0958	88	28.0113	138	43.9268	188	59.8423
39	12.4141	89	28.3296	139	44.2451	189	60.1606
40	12.7324	90	28.6479	140	44.5634	190	60.4789
41	13.0507	91	28.9662	141	44.8817	191	60.7972
42	13.3690	92	29.2845	142	45.2000	192	61.1155
43	13.6873	93	29.6028	143	45.5183	193	61.4338
44	14.0056	94	29.9211	144	45.8366	194	61.7521
45	14.3239	95	30.2394	145	46.1549	195	62.0704
46	14.6423	96	30.5577	146	46.4732	196	62.3887
47	14.9606	97	30.8761	147	46.7916	197	62.7070
48	15,2789	98	31.1944	148	47.1099	198	63.0254
49	15,5972	99	31.5127	149	47.4282	199	63.3437
50	15.9155	100	31.8310	150	47.7465	200	63.6620

Reciprocals of Numbers from 1 to 1000

No.	Reciprocal	No.	Reciprocal	No.	Reciprocal	No.	Reciprocal
1	1.00000000	51	.01960784	101	.00990099	151	.00662252
2	.50000000	52	.01923077	102	.00980392	152	.00657895
3	.33333333	53	.01886792	103	.00970874	153	.00653595
4	.25000000	54	.01851852	104	.00961538	154	.00649351
5	.20000000	55	.01818182	105	.00952381	155	.00645161
6	.16666667	56	.01785714	106	.00943396	156	.00641026
7	.14285714	57	.01754386	107	.00934579	157	.00636943
8	.12500000	58	.01724138	108	.00925926	158	.00632911
9	.11111111	59	.01694915	109	.00917431	159	.00628931
10	.10000000	60	.01666667	110	.00909091	160	.00625000
11	.09090909	61	.01639344	111	.00900901	161	.00621118
12	.08333333	62	.01612903	112	.00892857	162	.00617284
13	.07692308	63	.01587302	113	.00884956	163	.00613497
14	.07142857	64	.01562500	114	.00877193	164	.00609756
15	.06666667	65	.01538461	115	.00869565	165	.00606061
16	.06250000	66	.01515151	116	.00862069	166	.00602410
17	.05882353	67	.01492537	117	.00854701	167	.00598802
18	.05555556	68	.01470588	118	.00847458	168	.00595238
19	.05263158	69	.01449275	119	.00840336	169	.00591716
20	.05000000	70	.01428571	120	.00833333	170	.00588235
21	.04761905	71	.01408451	121	.00826446	171	.00584795
22	.04545455	72	.01388889	122	.00819672	172	.00581395
23	.04347826	73	.01369863	123	.00813008	173	.00578035
24	.04166667	74	.01351351	124	.00806452	174	.00574713
25	.04000000	75	.01333333	125	.00800000	175	.00571429
26	.03846154	76	.01315789	126	.00793651	176	.00568182
27	.03703704	77	.01298701	127	.00787402	177	.00564972
28	.03571429	78	.01282051	128	.00781250	178	.00561798
29	.03448276	79	.01265823	129	.00775194	179	.00558659
30	.03333333	80	.01250000	130	.00769231	180	.00555556
31	.03225806	81	.01234568	131	.00763359	181	.00552486
32	.03125000	82	.01219512	132	.00757576	182	.00549451
33	.03030303	83	.01204819	133	.00751880	183	.00546448
34	.02941176	84	.01190476	134	.00746269	184	.00543478
35	.02857143	85	.01176471	135	.00740741	185	.00540540
36	.02777778	86	.01162791	136	.00735294	186	.00537634
37	.02702703	87	.01149425	137	.00729927	187	.00534759
38	.02631579	88	.01136364	138	.00724638	188	.00531914
39	.02564103	89	.01123595	139	.00719424	189	.00529100
40	.02500000	90	.01111111	140	.00714286	190	.00526316
41	.02439024	91	.01098901	141	.00709220	191	.00523560
42	.02380952	92	.01086956	142	.00704225	192	.00520833
43	.02325581	93	.01075269	143	.00699301	193	.00518135
44	.02272727	94	.01063830	144	.00694444	194	.00515464
45	.02222222	95	.01052632	145	.00689655	195	.00512820
46	.02173913	96	.01041667	146	.00684931	196	.00510204
47	.02127660	97	.01030928	147	.00680272	197	.00507614
48	.02083333	98	.01020408	148	.00675676	198	.00505051
49	.02040816	99	.01010101	149	.00671141	199	.00502513
50	.02000000	100	.01000000	150	.00666667	200	.00500000

Reciprocals of Numbers from 1 to 1000

No.	Reciprocal	No.	Reciprocal	No.	Reciprocal	No.	Reciprocal
201	.00497512	251	.00398406	301	.00332226	351	.00284900
202	.00495049	252	.00396825	302	.00331126	352	.00284091
203	.00492611	253	.00395257	303	.00330033	353	.00283286
204	.00490196	254	.00393701	304	.00328947	354	.00282486
205	.00487805	255	.00392157	305	.00327869	355	.00281690
206	.00485437	256	.00390625	306	.00326797	356	.00280899
207	.00483092	257	.00389105	307	.00325733	357	.00280112
208	.00480769	258	.00387597	308	.00324675	358	.00279330
209	.00478469	259	.00386100	309	.00323625	359	.00278551
210	.00476190	260	.00384615	310	.00322581	360	.00277778
211	.00473934	261	.00383142	311	.00321543	361	.00277008
212	.00471698	262	.03381679	312	.00320513	362	.00276243
213	.00469484	263	.00380228	313	.00319489	363	.00275482
214	.00467290	264	.00378788	314	.00318471	364	.00274725
215	.00465116	265	.00377358	315	.00317460	365	.00273973
216	.00462963	266	.00375940	316	.00316456	366	.00273224
217	.00460829	267	.00374532	317	.00315457	367	.00272480
218	.00458716	268	.00373134	318	.00314465	368	.00271739
219	.00456621	269	.00371747	319	.00313480	369	.00271003
220	.00454545	270	.00370370	320	.00312500	370	.00270270
221	.00452489	271	.00369004	321	.00311526	371	.00269542
222	.00450450	272	.00367647	322	.00310559	372	.00268817
223	.00448430	273	.00366300	323	.00309597	373	.00268096
224	.00446429	274	.00364963	324	.00308642	374	.00267380
225	.00444444	275	.00363636	325	.00307692	375	.00266667
226	.00442478	276	.00362319	326	.00306748	376	.00265957
227	.00440529	277	.00361011	327	.00305810	377	.00265252
228	.00438596	278	.00359712	328	.00304878	378	.00264550
229	.00436681	279	.00358423	329	.00303951	379	.00263852
230	.00434783	280	.00357143	330	.00303030	380	.00263158
231	.00432900	281	.00355872	331	.00302115	381	.00262467
232	.00431034	282	.00354610	332	.00301205	382	.00261780
233	.00429184	283	.00353357	333	.00300300	383	.00261097
234	.00427350	284	.00352113	334	.00299401	384	.00260417
235	.00425532	285	.00350877	335	.00298507	385	.00259740
236	.00423729	286	.00349650	336	.00297619	386	.00259067
237	.00421941	287	.00348432	337	.00296736	387	.00258398
238	.00420168	288	.00347222	338	.00295858	388	.00257732
239	.00418410	289	.00346021	339	.00294985	389	.00257069
240	.00416667	290	.00344828	340	.00294118	390	.00256410
241	.00414938	291	.00343643	341	.00293255	391	.00255754
242	.00413223	292	.00342466	342	.00292398	392	.00255102
243	.00411523	293	.00341297	343	.00291545	393	.00254453
244	.00409836	294	.00340136	344	.00290698	394	.00253807
245	.00408163	295	.00338983	345	.00289855	395	.00253165
246	.00406504	296	.00337838	346	.00289017	396	.00252525
247	.00404858	297	.00336700	347	.00288184	397	.00251889
248	.00403226	298	.00335570	348	.00287356	398	.00251256
249	.00401606	299	.00334448	349	.00286533	399	.00250627
250	.00400000	300	.00333333	350	.00285714	400	.00250000

Reciprocals of Numbers from 100 to 1000

No.	Reciprocal	No.	Reciprocal	No.	Reciprocal	No.	Reciprocal
401	.00249377	451	.00221729	501	.00199601	551	.00181488
402	.00248756	452	.00221239	502	.00199203	552	.00181159
403	.00248139	453	.00220751	503	.00198807	553	.00180832
404	.00247525	454	.00220264	504	.00198413	554	.00180505
405	.00246914	455	.00219780	505	.00198020	555	.00180180
406	.00246305	456	.00219298	506	.00197628	556	.00179856
407	.00245700	457	.00218818	507	.00197239	557	.00179533
408	.00245098	458	.00218341	508	.00196850	558	.00179211
409	.00244499	459	.00217865	509	.00196464	559	.00178891
410	.00243902	460	.00217391	510	.00196078	560	.00178571
411	.00243309	461	.00216920	511	.00195695	561	.00178253
412	.00242718	462	.00216450	512	.00195312	562	.00177936
413	.00242131	463	.00215983	513	.00194932	563	.00177620
414	.00241546	464	.00215517	514	.00194552	564	.00177305
415	.00240964	465	.00215054	515	.00194175	565	.00176991
416	.00240385	466	.00214592	516	.00193798	566	.00176678
417	.00239808	467	.00214133	517	.00193424	567	.00176367
418	.00239234	468	.00213675	518	.00193050	568	.00176056
419	.00238663	469	.00213220	519	.00192678	569	.00175747
420	.00238095	470	.00212766	520	.00192308	570	.00175439
421	.00237530	471	.00212314	521	.00191939	571	.00175131
422	.00236967	472	.00211864	522	.00191571	572	.00174825
423	.00236407	473	.00211416	523	.00191205	573	.00174520
424	.00235849	474	.00210970	524	.00190840	574	.00174216
425	.00235294	475	.00210526	525	.00190476	575	.00173913
426	.00234742	476	.00210084	526	.00190114	576	.00173611
427	.00234192	477	.00209644	527	.00189753	577	.00173310
428	.00233645	478	.00209205	528	.00189394	578	.00173010
429	.00233100	479	.00208768	529	.00189036	579	.00172712
430	.00232558	480	.00208333	530	.00188679	580	.00172414
431	.00232019	481	.00207900	531	.00188324	581	.00172117
432	.00231481	482	.00207469	532	.00187970	582	.00171821
433	.00230947	483	.00207039	533	.00187617	583	.00171527
434	.00230415	484	.00206612	534	.00187266	584	.00171233
435	.00229885	485	.00206186	535	.00186916	585	.00170940
436	.00229358	486	.00205761	536	.00186567	586	.00170648
437	.00228833	487	.00205339	537	.00186220	587	.00170358
438	.00228310	488	.00204918	538	.00185874	588	.00170068
439	.00227790	489	.00204499	538	.00185528	589	.00169779
440	.00227273	490	.00204082	540	.00185185	590	.00169491
441	.00226757	491	.00203666	541	.00184843	591	.00169205
442	.00226244	492	.00203252	542	.00184502	592	.00168919
443	.00225734	493	.00202840	543	.00184162	593	.00168634
444	.00225225	494	.00202429	544	.00183823	594	.00168350
445	.00224719	495	.00202020	545	.00183486	595	.00168067
446	.00224215	496	.00201613	546	.00183150	596	.00167785
447	.00223714	497	.00201207	547	.00182815	597	.00167504
448	.00223214	498	.00200803	548	.00182482	598	.00167224
449	.00222717	499	.00200401	549	.00182149	599	.00166945
450	.00222222	500	.00200000	550	.00181818	600	.00166667

Reciprocals of Numbers from 1 to 1000

No.	Reciprocal	No.	Reciprocal	No.	Reciprocal	No.	Reciprocal
601	.00166389	651	.00153610	701	.00142653	751	.00133156
602	.00166113	652	.00153374	702	.00142450	752	.00132979
603	.00165837	653	.00153140	703	.00142247	753	.00132802
604	.00165563	654	.00152905	704	.00142045	754	.00132626
605	.00165289	655	.00152672	705	.00141844	755	.00132450
606	.00165016	656	.00152439	706	.00141643	756	.00132275
607	.00164745	657	.00152207	707	.00141443	757	.00132100
608	.00164474	658	.00151975	708	.00141243	758	.00131926
609	.00164204	659	.00151745	709	.00141044	759	.00131752
610	.00163934	660	.00151515	710	.00140845	760	.00131579
611	.00163666	661	.00151286	711	.00140647	761	.00131406
612	.00163399	662	.00151057	712	.00140449	762	.00131234
613	.00163132	663	.00150830	713	.00140252	763	.00131062
614	.00162866	664	.00150602	714	.00140056	764	.00130890
615	.00162602	665	.00150376	715	.00139860	765	.00130719
616	.00162338	666	.00150150	716	.00139665	766	.00130548
617	.00162075	667	.00149925	717	.00139470	767	.00130378
618	.00161812	668	.00149701	718	.00139276	768	.00130208
619	.00161551	669	.00149477	719	.00139082	769	.00130039
620	.00161290	670	.00149254	720	.00138889	770	.00129870
621	.00161031	671	.00149031	721	.00138696	771	.00129702
622	.00160772	672	.00148809	722	.00138504	772	.00129534
623	.00160514	673	.00148588	723	.00138313	773	.00129366
624	.00160256	674	.00148368	724	.00138121	774	.00129199
625	.00160000	675	.00148148	725	.00137931	775	.00129032
626	.00159744	676	.00147929	726	.00137741	776	.00128866
627	.00159490	677	.00147710	727	.00137552	777	.00128700
628	.00159236	678	.00147493	728	.00137363	778	.00128535
629	.00158982	679	.00147275	729	.00137174	779	.00128370
630	.00158730	680	.00147059	730	.00136986	780	.00128205
631	.00158479	681	.00146843	731	.00136799	781	.00128041
632	.00158228	682	.00146628	732	.00136612	782	.00127877
633	.00157978	683	.00146413	733	.00136426	783	.00127714
634	.00157729	684	.00146199	734	.00136240	784	.00127551
635	.00157480	685	.00145985	735	.00136054	785	.00127388
636	.00157233	686	.00145773	736	.00135870	786	.00127226
637	.00156986	687	.00145560	737	.00135685	787	.00127065
638	.00156740	688	.00145349	738	.00135501	788	.00126904
639	.00156494	689	.00145137	739	.00135318	789	.00126743
640	.00156250	690	.00144927	740	.00135135	790	.00126582
641	.00156006	691	.00144718	741	.00134953	791	.00126422
642	.00155763	692	.00144509	742	.00134771	792	.00126263
643	.00155521	693	.00144300	743	.00134589	793	.00126103
644	.00155279	694	.00144092	744	.00134409	794	.00125945
645	.00155039	695	.00143885	745	.00134228	795	.00125786
646	.00154799	696	.00143678	746	.00134048	796	.00125628
647	.00154559	697	.00143472	747	.00133869	797	.00125470
648	.00154321	698	.00143266	748	.00133690	798	.00125313
649	.00154083	699	.00143061	749	.00133511	799	.00125156
650	.00153846	700	.00142857	750	.00133333	800	.00125000

Reciprocals of Numbers from 1 to 1000

No.	Reciprocal	No.	Reciprocal	No.	Reciprocal	No.	Reciprocal
801	.00124844	851	.00117509	901	.00110988	951	.00105152
802	.00124688	852	.00117371	902	.00110865	952	.00105042
803	.00124533	853	.00117233	903	.00110742	953	.00104932
803	.00124378	854	.00117096	904	.00110619	954	.00104822
805	.00124224	855	.00116959	905	.00110497	955	.00104712
806	.00124069	856	.00116822	906	.00110375	956	.00104602
807	.00123916	857	.00116686	907	.00110254	957	.00104493
808	.00123762	858	.00116550	908	.00110132	958	.00104384
809	.00123609	859	.00116414	909	.00110011	959	.00104275
810	.00123457	860	.00116279	910	.00109890	960	.00104167
811	.00123305	861	.00116144	911	.00109769	961	.00104058
812	.00123153	862	.00116009	912	.00109649	962	.00103950
813	.00124001	863	.00115875	913	.00109529	963	.00103842
814	.00122850	864	.00115741	914	.00109409	964	.00103734
815	.00122699	865	.00115607	915	.00109290	965	.00103627
816	.00122549	866	.00115473	916	.00109170	966	.00103520
817	.00122399	867	.00115340	917	.00109051	967	.00103413
818	.00122249	868	.00115207	918	.00108932	968	.00103306
819	.00122100	869	.00115075	919	.00108814	969	.00103199
820	.00121951	870	.00114942	920	.00108696	970	.00103093
821	.00121803	871	.00114811	921	.00108578	971	.00102987
822	.00121654	872	.00114679	922	.00108460	972	.00102881
823	.00121507	873	.00114547	923	.00108342	973	.00102775
824	.00121359	874	.00114416	924	.00108225	974	.00102669
825	.00121212	875	.00114286	925	.00108108	975	.00102564
826	.00121065	876	.00114155	926	.00107991	976	.00102459
827	.00120919	877	.00114025	927	.00107875	977	.00102354
828	.00120773	878	.00113895	928	.00107759	978	.00102250
829	.00120627	879	.00113766	929	.00107643	979	.00102145
830	.00120482	880	.00113636	930	.00107527	980	.00102041
831	.00120337	881	.00113507	931	.00107411	981	.00101937
832	.00120192	882	.00113379	932	.00107296	982	.00101833
833	.00120048	883	.00113250	933	.00107181	983	.00101729
834	.00119904	884	.00113122	934	.00107066	984	.00101626
835	.00119760	885	.00112994	935	.00106952	985	.00101523
836	.00119617	886	.00112867	936	.00106838	986	.00101420
837	.00119474	887	.00112740	937	.00106724	987	.00101317
838	.00119332	888	.00112613	938	.00106610	988	.00101215
839	.00119189	889	.00112486	939	.00106496	989	.00101112
840	.00119048	890	.00112360	940	.00106383	990	.00101010
841	.00118906	891	.00112233	941	.00106270	991	.00100908
842	.00118765	892	.00112108	942	.00106157	992	.00100806
843	.00118624	893	.00111982	943	.00106044	993	.00100705
844	.00118483	894	.00111857	944	.00105932	994	.00100604
845	.00118343	895	.00111732	945	.00105820	995	.00100502
846	.00118203	896	.00111607	946	.00105708	996	.00100402
847	.00118064	897	.00111483	947	.00105597	997	.00100301
848	.00117924	898	.00111359	948	.00105485	998	.00100200
849	.00117786	899	.00111235	949	.00105374	999	.00100100
850	.00117647	900	.00111111	950	.00105263	1000	.00100000

AUTOMOTIVE

Automotive Data

Considerable information relating to automotive practice will be found in other sections, as it seems best to put S.A.E. threads, bolts, nuts, steels, etc. with other data on the same subject. This section is entirely automotive material although it by no means represents all the information on automotive subjects.

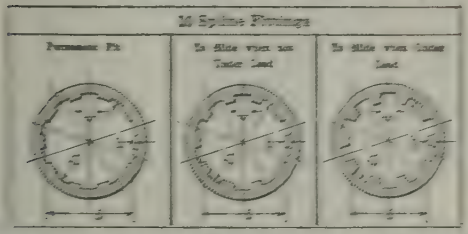
TABLE 1.—TESTS OF STUD HOLES WITH DIFFERENT DEPTHS OF THREADS

Pitch Diam.		⅜ × 18 Studs						
Stud, in Inches	Hole, in Inches	Pitch Diam. Interference in Inches	Minor Diam. Hole, in Inches	Percentage Depth of Thread	Material	Elastic Limit in Pounds	Maximum Stress in Pounds	Remarks
0.282	0.278	0.004	0.257	75	Cast iron	3,800	6,000	Stud broke
0.2775	0.278		0.257	75	Cast iron	3,850	6,450	Stud broke
0.282	0.278	0.004	0.2056	65	Cast iron	3,050	6,025	Stud broke
0.2775	0.278		0.2056	65	Cast iron	2,325	5,525	Stud broke
0.2775	0.278		0.272	56	Cast iron	3,750	6,600	Stud broke
0.2775	0.278		0.277	49	Cast iron	3,500	5,950	Stud broke
0.2775	0.278		0.2812	43	Cast iron	2,700	5,700	Stud broke
0.2815	0.278	0.0035	0.2812	43	Aluminum	2,800	5,850	Stud broke
0.281	0.278	0.003	0.2812	43	Aluminum	2,400	5,850	Stud broke
0.278	0.278		0.2812	43	Aluminum	3,200	5,450	Stud broke
		7/16 × 14 Studs						
0.3937	0.3927	0.001	0.397	43	Aluminum	6,150	9,400	Stud broke
0.3937	0.3927	0.001	0.397	43	Aluminum	7,500	10,000	Stud broke
		½ × 13 Studs						
0.453	0.453		0.4531	47	Cast iron		16,750	Stud broke
		½ × 20 Studs						
0.4691	0.4691		0.4531	72	Mall. iron		17,410	Stud broke
0.4691	0.4691		0.475	39	Mall. iron		17,925	Stud broke
0.4685	0.468	0.0005	0.475	39	Mall. iron		17,000	Threads strippe in holed due tobad material

Spline Shaft Fittings

Dimensions for spline shaft fittings have been carefully selected and tolerances provided for all essential dimensions so as to give fittings of the following types. There are three general classifications for each number of splines to cover the three conditions in which they are used—permanent fits fitting when not under load and sliding under load. The letters used in dimensioning are shown in connection with the 10-spline shaft but are the same in all

D = nominal outside diameter
d = nominal inside diameter
w = width of spline, arcual
h = height of tooth or $\frac{1}{2}(D - d)$



FORMULA FOR FINDING ROOT WIDTH OF SPLINEWAYS

The following formula will be found useful for calculating the root width of splineways or toothed shafts

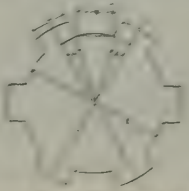
$$\sin\left(\frac{180^\circ}{N} - \sin^{-1}\frac{B}{2}\right) \times B = W$$

in which N = number of splines and B = diameter of shaft at the root of the splineway.

Angle A must first be computed as follows

$$\sin A = \frac{T}{2} \div \frac{B}{2} \quad \text{or} \quad \sin A = \frac{T}{B}$$

in which T = width of spline and B = diameter of shaft at root of splineway.



Calculating Root Width of Splineways

Dimensions for 4-spline Shaft Fittings
(Dimensions in Inches)

4A—Permanent Fit

Nom. Diam.	D		d		W		h		T^1
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	
$\frac{3}{4}$	0.750	0.749	0.637	0.636	0.181	0.179	0.056	0.055	78
$\frac{7}{8}$	0.875	0.874	0.744	0.743	0.211	0.209	0.066	0.065	107
1	1.000	0.999	0.850	0.849	0.241	0.239	0.075	0.074	139
$1\frac{1}{8}$	1.125	1.124	0.956	0.955	0.271	0.269	0.084	0.083	175
$1\frac{1}{4}$	1.250	1.249	1.062	1.061	0.301	0.299	0.094	0.093	217
$1\frac{3}{8}$	1.375	1.374	1.169	1.168	0.331	0.329	0.103	0.102	262
$1\frac{1}{2}$	1.500	1.499	1.275	1.274	0.361	0.359	0.112	0.111	311
$1\frac{5}{8}$	1.625	1.624	1.381	1.380	0.391	0.389	0.122	0.121	367
$1\frac{3}{4}$	1.750	1.749	1.487	1.486	0.422	0.420	0.131	0.130	424
2	2.000	1.998	1.700	1.698	0.482	0.479	0.150	0.148	555
$2\frac{1}{4}$	2.250	2.248	1.912	1.910	0.542	0.539	0.169	0.167	703
$2\frac{1}{2}$	2.500	2.498	2.125	2.123	0.602	0.599	0.187	0.185	865
3	3.000	2.998	2.550	2.548	0.723	0.720	0.225	0.223	1,249

4B—To Slide When Not under Load

Nom. Diam.	D		d		W		h		T^1
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	
$\frac{3}{4}$	0.750	0.749	0.562	0.561	0.181	0.179	0.094	0.093	123
$\frac{7}{8}$	0.875	0.874	0.656	0.655	0.211	0.209	0.109	0.108	167
1	1.000	0.999	0.750	0.749	0.241	0.239	0.125	0.124	216
$1\frac{1}{8}$	1.125	1.124	0.844	0.843	0.271	0.269	0.141	0.140	277
$1\frac{1}{4}$	1.250	1.249	0.937	0.936	0.301	0.299	0.156	0.155	341
$1\frac{3}{8}$	1.375	1.374	1.031	1.030	0.331	0.329	0.172	0.171	414
$1\frac{1}{2}$	1.500	1.499	1.125	1.124	0.361	0.359	0.187	0.186	491
$1\frac{5}{8}$	1.625	1.624	1.219	1.218	0.391	0.389	0.203	0.202	577
$1\frac{3}{4}$	1.750	1.749	1.312	1.311	0.422	0.420	0.219	0.218	670
2	2.000	1.998	1.500	1.498	0.482	0.479	0.250	0.248	875
$2\frac{1}{4}$	2.250	2.248	1.687	1.685	0.542	0.539	0.281	0.279	1,106
$2\frac{1}{2}$	2.500	2.498	1.875	1.873	0.602	0.599	0.312	0.310	1,365
3	3.000	2.998	2.250	2.248	0.723	0.720	0.375	0.373	1,969

Radii on corners of splines not to exceed 0.015 inch. Splines shall not be more than 0.006 inch per foot out of parallel with respect to the axis of the shaft.

[1] Torque = 1,000 × 4 × mean $R \times h \times 1$ = pound-inches torque capacity per inch of bearing length at 1,000 pounds per square inch pressure on sides of splines.

No allowance is made for radii on corners or for clearances.

Dimensions are intended to apply to only the soft-broached hole. Allowance must be made for machining the shaft to give the required fit.

Dimensions for 6-spline Shaft Fittings
(Dimensions in Inches)

6A—Permanent Fit								6B—To Slide When Not under Load								6C—To Slide When under Load							
Nom. Diam.	D		d		W		T^1	Nom. Diam.	D		d		W		T^1	Nom. Diam.	D		d		W		T^1
	Max.	Min.	Max.	Min.	Max.	Min.			Max.	Min.	Max.	Min.	Max.	Min.			Max.	Min.	Max.	Min.	Max.	Min.	
$\frac{3}{4}$	0.750	0.749	0.675	0.674	0.188	0.186	80	$\frac{3}{4}$	0.750	0.749	0.638	0.637	0.188	0.187	117	$\frac{3}{4}$	0.750	0.749	0.600	0.599	0.188	0.186	152
$\frac{7}{8}$	0.875	0.874	0.788	0.787	0.219	0.217	109	$\frac{7}{8}$	0.875	0.874	0.744	0.743	0.219	0.217	159	$\frac{7}{8}$	0.875	0.874	0.700	0.699	0.219	0.217	207
1	1.000	0.999	0.900	0.899	0.250	0.248	143	1	1.000	0.999	0.850	0.849	0.250	0.248	208	1	1.000	0.999	0.800	0.799	0.250	0.248	270
$1\frac{1}{8}$	1.125	1.124	1.013	1.012	0.281	0.279	180	$1\frac{1}{8}$	1.125	1.124	0.956	0.955	0.281	0.279	263	$1\frac{1}{8}$	1.125	1.124	0.900	0.899	0.281	0.279	342
$1\frac{1}{4}$	1.250	1.249	1.125	1.124	0.313	0.311	223	$1\frac{1}{4}$	1.250	1.249	1.063	1.062	0.313	0.311	325	$1\frac{1}{4}$	1.250	1.249	1.000	0.999	0.313	0.311	421
$1\frac{3}{8}$	1.375	1.374	1.238	1.237	0.344	0.342	269	$1\frac{3}{8}$	1.375	1.374	1.169	1.168	0.344	0.342	393	$1\frac{3}{8}$	1.375	1.374	1.100	1.099	0.344	0.342	510
$1\frac{1}{2}$	1.500	1.499	1.350	1.349	0.375	0.373	321	$1\frac{1}{2}$	1.500	1.499	1.275	1.274	0.375	0.373	468	$1\frac{1}{2}$	1.500	1.499	1.200	1.199	0.375	0.373	608
$1\frac{5}{8}$	1.625	1.624	1.463	1.462	0.406	0.404	376	$1\frac{5}{8}$	1.625	1.624	1.381	1.380	0.406	0.404	550	$1\frac{5}{8}$	1.625	1.624	1.300	1.299	0.406	0.404	713
$1\frac{3}{4}$	1.750	1.749	1.575	1.574	0.438	0.436	436	$1\frac{3}{4}$	1.750	1.749	1.488	1.487	0.438	0.436	637	$1\frac{3}{4}$	1.750	1.749	1.400	1.399	0.438	0.436	827
2	2.000	1.998	1.800	1.798	0.500	0.497	570	2	2.000	1.998	1.700	1.698	0.500	0.497	833	2	2.000	1.998	1.600	1.598	0.500	0.497	1,080
$2\frac{1}{4}$	2.250	2.248	2.025	2.023	0.563	0.560	721	$2\frac{1}{4}$	2.250	2.248	1.913	1.911	0.563	0.560	1052	$2\frac{1}{4}$	2.250	2.248	1.800	1.798	0.563	0.560	1,367
$2\frac{1}{2}$	2.500	2.498	2.250	2.248	0.625	0.622	891	$2\frac{1}{2}$	2.500	2.498	2.125	2.123	0.625	0.622	1300	$2\frac{1}{2}$	2.500	2.498	2.000	1.998	0.625	0.622	1,688
3	3.000	2.998	2.700	2.698	0.750	0.747	1283	3	3.000	2.998	2.550	2.548	0.750	0.747	1873	3	3.000	2.998	2.400	2.398	0.750	0.747	2,430

Radii on corners of splines not to exceed 0.015 inch.

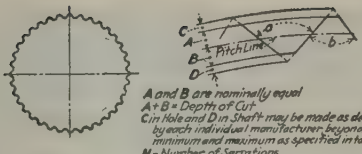
Splines shall not be more than 0.000 inch per foot out of parallel with respect to the axis of the shaft.

[1] Torque = 1,000 × 6 × mean $R \times h \times 1$ = pound-inches torque capacity per inch of bearing at 1,000 pounds per square inch pressure on sides of splines.

Dimensions for 10-spline Shaft Fittings
(Dimensions in Inches)

Nom. Diam.	10A—Permanent Fit							10B—To Slide When Not under Load							10C—To Slide When under Load						
	D		d		W		T_1	Nom. Diam.	D		d		W		T_1	Nom. Diam.	D		d		W		T^1
	Max.	Min.	Max.	Min.	Max.	Min.			Max.	Min.	Max.	Min.	Max.	Min.			Max.	Min.	Max.	Min.	Max.	Min.	
3/4	0.750	0.749	0.683	0.682	0.117	0.115	120	3/4	0.750	0.749	0.645	0.644	0.117	0.115	183	3/4	0.750	0.749	0.608	0.607	0.117	0.115	241
	0.875	0.874	0.796	0.795	0.137	0.135	165		0.875	0.874	0.753	0.752	0.137	0.135	248		0.875	0.874	0.709	0.708	0.137	0.135	329
1	1.000	0.999	0.910	0.909	0.156	0.154	215	1	1.000	0.999	0.860	0.859	0.156	0.154	326	1	1.000	0.999	0.810	0.809	0.156	0.154	430
1 1/4	1.125	1.124	1.024	1.023	0.176	0.174	271	1 1/4	1.125	1.124	0.968	0.967	0.176	0.174	412	1 1/4	1.125	1.124	0.911	0.910	0.176	0.174	545
1 1/2	1.250	1.249	1.138	1.137	0.195	0.193	336	1 1/2	1.250	1.249	1.075	1.074	0.195	0.193	508	1 1/2	1.250	1.249	1.013	0.012	0.195	0.193	672
1 3/4	1.375	1.374	1.251	1.250	0.215	0.213	406	1 3/4	1.375	1.374	1.183	1.182	0.215	0.213	614	1 3/4	1.375	1.374	1.114	1.113	0.215	0.213	813
1 3/4	1.500	1.499	1.365	1.364	0.234	0.232	483	1 3/4	1.500	1.499	1.290	1.289	0.234	0.232	732	1 3/4	1.500	1.499	1.215	1.214	0.234	0.232	967
1 3/4	1.625	1.624	1.479	1.478	0.254	0.252	566	1 3/4	1.625	1.624	1.398	1.397	0.254	0.252	860	1 3/4	1.625	1.624	1.316	1.315	0.254	0 252	1,135
1 3/4	1.750	1.749	1.593	1.592	0.273	0.271	658	1 3/4	1.750	1.749	1.505	1.504	0.273	0.271	997	1 3/4	1.750	1.749	1.418	1.417	0.273	0 271	1,316
2	2.000	1.998	1.820	1.818	0.312	0.309	860	2	2.000	1.998	1.720	1.718	0.312	0.309	1302	2	2.000	1.998	1.620	1.618	0.312	0.309	1,720
2 1/4	2.250	2.248	2.048	2.046	0.351	0.348	1088	2 1/4	2.250	2.248	1.935	1.933	0.351	0.348	1647	2 1/4	2.250	2.248	1.823	1.821	0.351	0.348	2,176
2 1/2	2.500	2.498	2.275	2.273	0.390	0.387	1343	2 1/2	2.500	2.498	2.150	2.148	0.390	0.387	2034	2 1/2	2.500	2.498	2.025	2.023	0.390	0.387	2,688
3	3.000	2.998	2.730	2.728	0.468	0.465	1934	3	3.000	2.998	2.580	2.578	0.468	0.465	2029	3	3.000	2.998	2.430	2.428	0.468	0.465	3,869
3 1/2	3.500	3.497	3.185	3.182	0.546	0.543	2632	3 1/2	3.500	3.497	3.010	3.007	0.546	0.543	3987	3 1/2	3.500	3.497	2.835	2.832	0.546	0.543	5,266
4	4.000	3.997	3.640	3.637	0.624	0.621	3438	4	4.000	3.997	3.440	3.437	0.624	0 621	5208	4	4.000	3.997	3.240	3.237	0.624	0.621	6,878
4 1/2	4.500	4.497	4.095	4.092	0 702	0.699	4351	4 1/2	4.500	4.497	3.870	3.867	0 702	0.699	6591	4 1/2	4.500	4.497	3.645	3.642	0.702	0.699	8,705
5	5.000	4.997	4.550	4.547	0.780	0.777	5371	5	5.000	4.997	4.300	4 297	0.780	0.777	8137	5	5 000	4 997	4.050	4.047	0.780	0.777	10,746
5 1/2	5.500	5.497	5.005	5.002	0.858	0.855	6500	5 1/2	5.500	5.497	4.730	4.727	0.858	0.855	9846	5 1/2	5.500	5 497	4.455	4.452	0.858	0.855	13,003
6	6.000	5.997	5.460	5.457	0.936	0.933	7735	6	6.000	5.997	5.160	5.157	0 936	0.933	11718	6	6.000	5.997	4.860	4.857	0 936	0.933	15,475

Radii on corners of splines not to exceed 0.015 inch.
Splines shall not be more than 0.006 inch per foot out of parallel with respect to the axis of the shaft.
[1] Torque = 1,000 × 10 × mean $R \times h \times 1$ = pound-inches torque capacity per inch of bearing length at 1,000 pounds per square inch pressure on sides of splines.



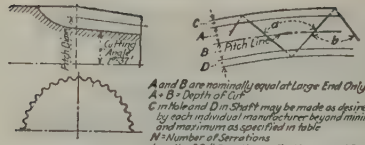
A and B are nominally equal
A + B = Depth of Cut
C in Hole and D in Shaft may be made as desired by each individual manufacturer beyond minimum and maximum as specified in table.
N = Number of Serrations

Serrated Shaft Fittings—S. A. E., 1922

STRAIGHT TYPE

(All Dimensions in Inches)

Nominal Diam.	Pitch Diam.		N	a, deg.	b, deg.	Hole			Shaft		
						Large Diam. Min.	Small Diam.		Outside Diam.		Inside Diam. Max.
	Max.	Min.					Max.	Min.	Max.	Min.	
$\frac{1}{8}$	0.122	0.120	36	90	80	0.125	0.118	0.117	0.124	0.123	0.116
$\frac{5}{32}$	0.182	0.180	36	90	80	0.187	0.176	0.175	0.186	0.185	0.174
$\frac{1}{4}$	0.243	0.241	36	90	80	0.250	0.235	0.234	0.249	0.248	0.233
$\frac{5}{16}$	0.303	0.301	36	90	80	0.312	0.293	0.292	0.311	0.310	0.291
$\frac{3}{8}$	0.363	0.361	36	90	80	0.375	0.352	0.351	0.374	0.373	0.350
$\frac{1}{2}$	0.485	0.483	36	90	80	0.500	0.469	0.468	0.499	0.498	0.467
$\frac{5}{8}$	0.605	0.603	36	90	80	0.625	0.584	0.583	0.624	0.623	0.582
$\frac{3}{4}$	0.733	0.731	48	90	$82\frac{1}{2}$	0.750	0.716	0.714	0.749	0.747	0.713
$\frac{7}{8}$	0.855	0.853	48	90	$82\frac{1}{2}$	0.875	0.835	0.833	0.874	0.872	0.832
1	0.977	0.975	48	90	$82\frac{1}{2}$	1.000	0.954	0.952	0.999	0.997	0.951
$1\frac{1}{8}$	1.098	1.096	48	90	$82\frac{1}{2}$	1.125	1.071	1.069	1.124	1.122	1.068
$1\frac{1}{4}$	1.220	1.218	48	90	$82\frac{1}{2}$	1.250	1.190	1.188	1.249	1.247	1.187
$1\frac{3}{8}$	1.342	1.340	48	90	$82\frac{1}{2}$	1.375	1.309	1.307	1.374	1.372	1.306
$1\frac{1}{2}$	1.464	1.462	48	90	$82\frac{1}{2}$	1.500	1.428	1.426	1.499	1.497	1.425
$1\frac{3}{4}$	1.708	1.706	48	90	$82\frac{1}{2}$	1.750	1.666	1.664	1.749	1.747	1.663
2	1.952	1.949	48	90	$82\frac{1}{2}$	2.000	1.904	1.902	1.999	1.997	1.901
$2\frac{1}{4}$	2.196	2.193	48	90	$82\frac{1}{2}$	2.250	2.142	2.140	2.249	2.247	2.139
$2\frac{1}{2}$	2.440	2.437	48	90	$82\frac{1}{2}$	2.500	2.380	2.378	2.499	2.497	2.377
$2\frac{3}{4}$	2.684	2.681	48	90	$82\frac{1}{2}$	2.750	2.618	2.616	2.749	2.747	2.615
3	2.928	2.925	48	90	$82\frac{1}{2}$	3.000	2.856	2.854	2.999	2.997	2.853



SERRATED SHAFT FITTINGS—S. A. E., 1922

TAPER TYPE

(All Dimensions in Inches and Apply to Large End of Taper Only)

Nominal Diam.	Pitch Diam.		N	a, deg.	b, deg.	Hole			Shaft		
						Large Diam. Min.	Small Diam.		Outside Diam.		Inside Diam. Min.
	Max.	Min.					Max.	Min.	Max.	Min.	
$\frac{1}{2}$	0.485	0.483	36	90	80	0.500	0.469	0.468	0.490	0.408	0.467
$\frac{5}{8}$	0.605	0.603	36	90	80	0.625	0.583	0.583	0.624	0.623	0.582
$\frac{3}{4}$	0.733	0.731	36	90	80	0.750	0.710	0.714	0.749	0.747	0.713
$\frac{7}{8}$	0.855	0.853	36	90	80	0.875	0.835	0.833	0.874	0.872	0.832
1	0.977	0.975	36	90	80	1.000	0.954	0.952	0.999	0.997	0.951
$1\frac{1}{8}$	1.098	1.096	36	90	80	1.125	1.071	1.069	1.124	1.122	1.068
$1\frac{1}{4}$	1.220	1.218	36	90	80	1.250	1.190	1.188	1.249	1.247	1.187
$1\frac{3}{8}$	1.342	1.340	36	90	80	1.375	0.309	1.307	1.374	1.372	1.306
$1\frac{1}{2}$	1.464	1.462	36	90	80	1.500	1.428	1.426	1.499	1.497	1.425
$1\frac{3}{4}$	1.708	1.706	36	90	80	1.750	1.666	1.664	1.749	0.747	1.663
2	1.952	1.949	48	90	$82\frac{1}{2}$	2.000	1.904	1.902	1.999	1.997	1.901
$2\frac{1}{4}$	2.196	2.193	48	90	$82\frac{1}{2}$	2.250	2.142	2.140	2.249	2.247	2.139
$2\frac{1}{2}$	2.440	2.437	48	90	$82\frac{1}{2}$	2.500	2.380	2.378	2.499	2.497	2.377
$2\frac{3}{4}$	2.684	2.681	48	90	$82\frac{1}{2}$	2.750	2.618	2.616	2.749	2.747	2.615
3	2.928	2.925	48	90	$82\frac{1}{2}$	3.000	2.856	2.854	2.999	2.997	2.853

Automobile Engine Pistons

Aluminum Alloy.—The main advantage of the aluminum or other light-alloy piston lies in its light weight, which is approximately half that of cast iron, on the average. The head conducts heat more rapidly than cast iron, but the metal is not so good for a wearing surface.

Clearance.—Many aluminum pistons have the skirt split at a slight angle, to allow for expansion, the angle prevents leaving a ridge in the cylinder. The clearance is about the same as for cast iron, 0.001 inch per inch of cylinder diameter, for water-cooled engines. The clearance of the top land is 0.005 inch, the second and third, 0.003 to 0.004 inch per inch of diameter.

Ring Fits.—The clearance recommended for the piston rings in the groove is from 0.001 to 0.0015 inch. This can be measured with a feeler. The gap in the ring is the same as for cast-iron pistons.

Machining.—Aluminum pistons are usually rough turned without lubricant at from 400 to 500 surface feet per minute. A cut $\frac{1}{32}$ inch deep and a feed of 0.025 inch per revolution are good practice. Tool should be keen and have about 15-degree top rake, about the same side clearance and 5-degree face clearance with a slightly rounded corner. Diamonds are sometimes used in finishing.

Grooves are cut with a parting tool, as close to the tool post as possible, and with plenty of side clearance. Top rake about 15 degrees and front clearance about 5 degrees. For roughing the grooves, run at 300 feet per minute and leave 0.005 inch on each side for finishing. Stone the tool carefully and run at 500 feet per minute.

Piston-Pin Holes.—Piston- or wrist-pin holes should be bored with from 0.003 to 0.005 inch left for reaming.

Grinding is recommended for finishing a 40-crystolon wheel or its equivalent, being used with a lubricant of one part kerosene and two parts mineral lard oil. If finished with a tool, use 500 feet per minute and 0.010- to 0.015-inch feed per revolution with tool point flat enough to cover feed.

Gap or Clearance between Ends.—Piston rings should clear the cylinder bore and have a proper gap between the ends. It is better to have gaps too large than too small. Rings having an angle cut should have 0.002-inch gap per inch of diameter for the top ring, half this for the second ring and about 0.00075 inch per inch of diameter for the third ring. Some fit the lower rings and rings in the skirt with ends touching, but a slight gap is more common practice.

With rings having a step cut instead of an angle cut, a greater gap between the ends is permissible, as the ends lap by each other.

For air-cooled motors some recommend about double the gap clearance given above.

Cast Iron. *Clearance in Cylinder Bore.*—A clearance of 0.001 inch for each inch of cylinder diameter may be called standard practice for piston skirts. For taxi, truck and tractor motors many recommend an extra 0.001 inch on the total, that is, a 4-inch piston should have a clearance of 0.004 plus an extra 0.001 or 0.005 inch total clearance. Some air-cooled motors require a little more clearance.

The clearance refers to the diameter of the skirt of the piston below the lowest ring in the head. The "lands" between the rings are smaller in diameter because of the greater heat and expansion due to the piston head. The top land should have 0.0035 inch clearance per inch of diameter, while the second land should have a clearance of 0.002 inch per inch of diameter.

If feelers are used to measure the clearance between the piston and cylinder wall, instead of inside and outside micrometers, an allowance must be made for the stiffness of the feeler, or its resistance to bending. It is recommended that 0.001 inch be allowed for this, *i.e.*, if a feeler 0.002 inch goes in, the real clearance is 0.001 greater or 0.003 inch.

Standard Oversize Pistons and Rings

After reviewing the practices of thirty passenger-car builders, six tractor, seven motorboat and fifteen truck and industrial-engine builders—the standard oversize pistons for passenger-car, marine and airplane engines, recommended are 0.003, 0.005, 0.010, 0.015 and 0.030 in. The standard oversizes for tractor, truck and industrial internal-combustion engines are 0.010, 0.020, 0.030 and 0.040 in. Larger sizes, when necessary, are to be held to multiples of 0.010 inch.

Piston rings are to be held to the same sizes, omitting that of 0.003 inch.

Clearance and Tolerances of Airplane Engines

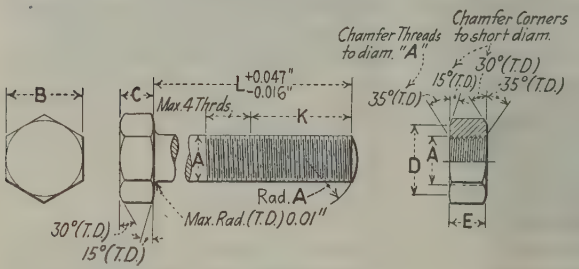
The following clearance on Liberty motor parts show the practice on close work of an accurate nature. They are from the official book.

SUMMARY OF CLEARANCES

	Min.	Max.	Desired
Crankshaft			
Diametrical clearance	0.0025	0.00325	
End play	0.0575	0.0775	
Connecting rods			
Forked end:			
Diametrical clearance	0.003	0.004	
End play	0.008	0.020	
Plain end:			
Diametrical clearance	0.005	0.0065	
End play	0.004	0.008	
Piston pin			
Fit in rod	0.00025	0.00125	Select for 0.001 clearance
Fit in piston	0.00025 loose	0.00075 tight	Select for light drive fit
Piston rings			
Fit in grooves	0.00125	0.003	Top 0.003 mid and bott. 0.002
Gap	0.021	0.041	0.030
Piston			
Fit in cylinder	0.018	0.022	Select for 0.020 clearance
Camshaft			
Diametrical clearance	0.001	0.003	
End play	0.000	0.004	Min. 0.002
Camshaft upper drive shaft			
Diametrical clearance:			
Large bushing	0.0005	0.0025	Min. 0.0015
Small bushing	0.0005	0.0025	Min. 0.0015
End play	0.002	0.008	Min. 0.004
Rocker levers			
Diametrical clearance	0.00025	0.00175	Min. 0.001
End play	0.005	0.010	0.0075
Valves			
Fit of stems in guides			
Diametrical clearance			
Exhaust valve	0.004	0.0065	0.005
Inlet valve	0.002	0.0045	0.003
Water pump shaft			
Diametrical clearance	0.0015	0.0035	Min. 0.0025
End play	0.006	0.010	0.010
Water pump bevel driver			
Diametrical clearance	0.001	0.0025	
End play	0.005	0.008	
Oil pump			
Fit of gears in housing			
Diametrical clearance	0.001	0.005	Select for 0.004 clearance
End play	0.002	0.007	Select for 0.003 clearance
Tappet gap			
Exhaust valve	0.019	0.021	
Inlet valve	0.013	0.016	
Breaker gap	0.010	0.013	
Spark plug gap	0.015	0.017	0.015
Regulator			
Contact pin	0.005	0.007	
Height of pin	0.043	0.045	

AERONAUTIC PLAIN HEXAGON-HEAD BOLTS AND NUTS

October, 1920



T.D. indicates tool dimensions.

C (for $\frac{1}{4}$ inch diam. and larger) $= \frac{A}{2} + \frac{1}{32}$ inch.

When body length $L =$	$\frac{1}{2}''$	$\frac{5}{8}''$	$\frac{3}{4}''$	$\frac{7}{8}''$	$1''$	Over $1''$
Length of thread $K =$	$\frac{3}{8}''$	$\frac{7}{16}''$	$\frac{1}{2}''$	$\frac{1}{2}''$	$\frac{1}{2}''$	$\frac{3}{4}''$

Plain Hexagon-head Bolt and Nut Dimensions

(All threads are U. S. Form. Dimensions in inches)

Nominal Bolt Size *A*	Threads per Inch	*A* Limits[1] (Bolt)		*B* Width across Flats	*C* ±0.005	*D* Width across Flats	*E*[2]	
		Max.	Min.				Full-strength Nuts ±0.005	Thin and Check Nuts ±0.005
0.1120 (No. 4)	48	0.1120	0.1090	0.250 (1/4)	0.094 (3/32)	0.250 (1/4)	0.094 (3/32)	0.094 (3/32)
0.1380 (No. 6)	40	0.1380	0.1350	0.313 (5/16)	0.094 (3/32)	0.313 (5/16)	0.109 (7/64)	0.109 (7/64)
0.1640 (No. 8)	32	0.1640	0.1610	0.313 (5/16)	0.125 (1/8)	0.375 (3/8)	0.125 (1/8)	0.125 (1/8)
0.1900 (No. 10)	32	0.1900	0.1870	0.375 (3/8)	0.125 (1/8)	0.375 (3/8)	0.141 (9/64)	0.141 (9/64)
0.2160 (No. 12)	28	0.2160	0.2120	0.375 (3/8)	0.125 (1/8)	0.438 (7/16)	0.156 (5/32)	0.156 (5/32)
0.2500 (1/4)—28	28	0.2500	0.2460	0.438 (7/16)	0.156 (5/32)	0.438 (7/16)	0.188 (3/16)	0.125 (1/8)
0.3125 (5/16)—24	24	0.3125	0.3085	0.500 (1/2)	0.188 (3/16)	0.500 (1/2)	0.234 (15/64)	0.156 (5/32)
0.3750 (3/8)—24	24	0.3750	0.3710	0.563 (9/16)	0.219 (7/32)	0.563 (9/16)	0.287 (9/32)	0.188 (3/16)
0.4375 (7/16)—20	20	0.4375	0.4335	0.688 (11/16)	0.250 (1/4)	0.688 (11/16)	0.328 (21/64)	0.219 (7/32)
0.5000 (1/2)—20	20	0.5000	0.4960	0.750 (3/4)	0.281 (9/32)	0.750 (3/4)	0.375 (3/8)	0.250 (1/4)
0.5625 (9/16)—18	18	0.5625	0.5575	0.875 (7/8)	0.313 (5/16)	0.875 (7/8)	0.422 (27/64)	0.281 (9/32)
0.6250 (5/8)—18	18	0.6250	0.6200	0.938 (15/16)	0.344 (11/32)	0.938 (15/16)	0.469 (15/32)	0.313 (5/16)

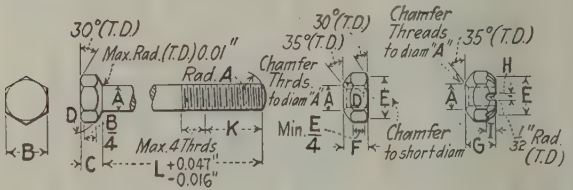
[1] Finished size including plating or rust-preventing treatment when used. The Bureau of Standards recommends a plate thickness of 0.001 inch to prevent rusting.

[2] For full-strength nuts, $E = \frac{3A}{4}$. For check nuts, and thin nuts for shear bolts $\frac{1}{4}$ inch diameter and larger, $E = \frac{A}{2}$.

These bolts are intended for use in bodies and wings, not in engines.

AERONAUTIC BALL HEXAGON-HEAD BOLTS AND NUTS

S. A. E., October, 1920



T.D. indicates tool dimensions.

When body length	$L =$	$\frac{1}{2}''$	$\frac{5}{8}''$	$\frac{3}{4}''$	$\frac{7}{8}''$	1" Over 1"
Length of minimum usable thread	$K =$	$\frac{3}{8}''$	$\frac{7}{16}''$	$\frac{1}{2}''$	$\frac{1}{2}''$	$\frac{1}{2}''$ $\frac{3}{4}''$

BALL HEXAGON-HEAD BOLT AND NUT DIMENSIONS
(All threads are U. S. Form. Dimensions in inches)

Nom. Bolt Size (*A*)	Threads per Inch	Bolt Diam. Limits, *A*[1]		*B* Width across Flats	*C*	*D* Rad.	*E* Width across Flats	*F* Ball Hexagon Nuts	Ball Castle Nuts		
		Max.	Min.						*G*[2]	*H*	*I*
0.1640 (No. 8)	32	0.1640	0.1610	0.313 ($\frac{5}{16}$)	0.172 ($\frac{11}{64}$)	0.375 ($\frac{3}{8}$)	0.375 ($\frac{3}{8}$)	0.172 ($\frac{11}{64}$)	0.250 ($\frac{1}{4}$)	0.078 ($\frac{5}{64}$)	0.078 ($\frac{5}{16}$)
0.1900 (No. 10)	32	0.1900	0.1870	0.375 ($\frac{3}{8}$)	0.172 ($\frac{11}{64}$)	0.375 ($\frac{3}{8}$)	0.375 ($\frac{3}{8}$)	0.172 ($\frac{11}{64}$)	0.250 ($\frac{1}{4}$)	0.078 ($\frac{5}{64}$)	0.078 ($\frac{5}{32}$)
0.2160 (No. 12)	28	0.2160	0.2120	0.375 ($\frac{3}{8}$)	0.172 ($\frac{11}{64}$)	0.375 ($\frac{3}{8}$)	0.438 ($\frac{7}{16}$)	0.172 ($\frac{11}{64}$)	0.266 ($\frac{17}{64}$)	0.078 ($\frac{5}{64}$)	0.094 ($\frac{3}{32}$)
0.2500 ($\frac{1}{4}$)	28	0.2500	0.2460	0.438 ($\frac{7}{16}$)	0.203 ($\frac{13}{64}$)	0.375 ($\frac{3}{8}$)	0.438 ($\frac{7}{16}$)	0.203 ($\frac{13}{64}$)	0.297 ($\frac{19}{64}$)	0.078 ($\frac{5}{64}$)	0.094 ($\frac{3}{32}$)
0.3125 ($\frac{5}{16}$)	24	0.3125	0.3085	0.500 ($\frac{1}{2}$)	0.250 ($\frac{1}{4}$)	0.375 ($\frac{3}{8}$)	0.500 ($\frac{1}{2}$)	0.250 ($\frac{1}{4}$)	0.344 ($\frac{11}{32}$)	0.078 ($\frac{5}{64}$)	0.094 ($\frac{3}{32}$)
0.3750 ($\frac{3}{8}$)	24	0.3750	0.3710	0.563 ($\frac{9}{16}$)	0.313 ($\frac{5}{16}$)	0.500 ($\frac{1}{2}$)	0.563 ($\frac{9}{16}$)	0.313 ($\frac{5}{16}$)	0.438 ($\frac{7}{16}$)	0.125 ($\frac{1}{8}$)	0.125 ($\frac{1}{8}$)
0.4375 ($\frac{7}{16}$)	20	0.4375	0.4335	0.688 ($\frac{11}{16}$)	0.359 ($\frac{23}{64}$)	0.500 ($\frac{1}{2}$)	0.688 ($\frac{11}{16}$)	0.359 ($\frac{23}{64}$)	0.484 ($\frac{31}{64}$)	0.125 ($\frac{1}{8}$)	0.125 ($\frac{1}{8}$)
0.5000 ($\frac{1}{2}$)	20	0.5000	0.4960	0.750 ($\frac{3}{4}$)	0.375 ($\frac{3}{8}$)	0.500 ($\frac{1}{2}$)	0.750 ($\frac{3}{4}$)	0.375 ($\frac{3}{8}$)	0.563 ($\frac{9}{16}$)	0.125 ($\frac{1}{8}$)	0.188 ($\frac{3}{16}$)
0.5625 ($\frac{9}{16}$)	18	0.5625	0.5575	0.875 ($\frac{7}{8}$)	0.469 ($\frac{15}{32}$)	0.625 ($\frac{5}{8}$)	0.875 ($\frac{7}{8}$)	0.469 ($\frac{15}{32}$)	0.659 ($\frac{21}{32}$)	0.156 ($\frac{5}{32}$)	0.188 ($\frac{3}{16}$)
0.6250 ($\frac{5}{8}$)	18	0.6200	0.6250	0.938 ($\frac{15}{16}$)	0.516 ($\frac{33}{64}$)	0.625 ($\frac{5}{8}$)	0.938 ($\frac{15}{16}$)	0.516 ($\frac{33}{64}$)	0.766 ($\frac{49}{64}$)	0.156 ($\frac{5}{32}$)	0.250 ($\frac{1}{4}$)

[1] Finished size, including plating or rust-preventing treatment when used. The Bureau of Standards recommends a plate thickness of 0.001 inch to prevent rusting.

[2] $G = F + I$.

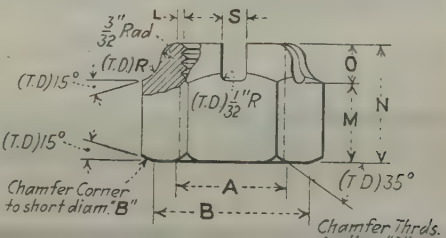
These bolts are intended for use in bodies and wings, not in engines.

Aeronautic Castle Hexagon Nuts
S. A. E., October, 1920
(Dimensions in Inches)

Bolt Size *A* Threads per Inch	*B*[1]	*N*	*S*	*O*[2]	*M*	*L*[3]	*R*
0.1640 (No. 8)—32	0.375 ($\frac{3}{8}$)	0.234 ($\frac{15}{64}$)	0.078 ($\frac{5}{64}$)	0.078 ($\frac{5}{64}$)	0.156 ($\frac{5}{32}$)	0.016 ($\frac{1}{64}$)	0.094 ($\frac{3}{32}$)
0.1900 (No. 10)—32	0.375 ($\frac{3}{8}$)	0.250 ($\frac{1}{4}$)	0.078 ($\frac{5}{64}$)	0.078 ($\frac{5}{64}$)	0.172 ($\frac{11}{64}$)	0.016 ($\frac{1}{64}$)	0.094 ($\frac{3}{32}$)
0.2160 (No. 12)—28	0.438 ($\frac{7}{16}$)	0.266 ($\frac{17}{64}$)	0.078 ($\frac{5}{64}$)	0.094 ($\frac{3}{32}$)	0.172 ($\frac{11}{64}$)	0.031 ($\frac{1}{32}$)	0.094 ($\frac{3}{32}$)
0.2500 ($\frac{1}{4}$)—28	0.438 ($\frac{7}{16}$)	0.281 ($\frac{9}{32}$)	0.078 ($\frac{5}{64}$)	0.094 ($\frac{3}{32}$)	0.188 ($\frac{3}{16}$)	0.031 ($\frac{1}{32}$)	0.094 ($\frac{3}{32}$)
0.3125 ($\frac{5}{16}$)—24	0.500 ($\frac{1}{2}$)	0.328 ($\frac{21}{64}$)	0.078 ($\frac{5}{64}$)	0.094 ($\frac{3}{32}$)	0.234 ($\frac{15}{64}$)	0.031 ($\frac{1}{32}$)	0.094 ($\frac{3}{32}$)
0.3750 ($\frac{3}{8}$)—24	0.563 ($\frac{9}{16}$)	0.406 ($\frac{13}{32}$)	0.125 ($\frac{1}{8}$)	0.125 ($\frac{1}{8}$)	0.281 ($\frac{9}{32}$)	0.031 ($\frac{1}{32}$)	0.094 ($\frac{3}{32}$)
0.4375 ($\frac{7}{16}$)—20	0.688 ($\frac{11}{16}$)	0.453 ($\frac{29}{64}$)	0.125 ($\frac{1}{8}$)	0.125 ($\frac{1}{8}$)	0.328 ($\frac{21}{64}$)	0.047 ($\frac{3}{64}$)	0.125 ($\frac{1}{8}$)
0.5000 ($\frac{1}{2}$)—20	0.750 ($\frac{3}{4}$)	0.563 ($\frac{9}{16}$)	0.125 ($\frac{1}{8}$)	0.188 ($\frac{3}{16}$)	0.375 ($\frac{3}{8}$)	0.047 ($\frac{3}{64}$)	0.125 ($\frac{1}{8}$)
0.5625 ($\frac{9}{16}$)—18	0.875 ($\frac{7}{8}$)	0.699 ($\frac{45}{64}$)	0.156 ($\frac{5}{32}$)	0.188 ($\frac{3}{16}$)	0.422 ($\frac{27}{64}$)	0.047 ($\frac{3}{64}$)	0.156 ($\frac{5}{32}$)
0.6250 ($\frac{5}{8}$)—18	0.938 ($\frac{15}{16}$)	0.719 ($\frac{23}{32}$)	0.156 ($\frac{5}{32}$)	0.250 ($\frac{1}{4}$)	0.469 ($\frac{15}{32}$)	0.047 ($\frac{3}{64}$)	0.156 ($\frac{5}{32}$)

[1] Also size of hexagon.
[2] Also depth of slot.
[3] Distance from *A* to beginning of $\frac{3}{32}$-inch radius whose center is floating to satisfy curve.

All threads are American Form.
T. D. indicates tool dimensions.
These bolts are intended for use in bodies and wings, not in engines.



AERONAUTIC ROUND HIGH-STRENGTH STEEL WIRE

S. A. E. Recommended Practice

This specification covers solid high-strength steel wire, round section, used in the construction of aircraft when flexibility is of minor importance.

Bend Test.—Samples for bend test shall be straight and not less than 10 inches long. One end of the sample shall be clamped between jaws having their upper edges rounded with $\frac{3}{16}$ (0.188)-inch radius. The free end of the wire shall be held loosely between two guides and bent 90 degrees over one jaw; this is to be counted as one bend. On raising to a vertical position the count will be two bends. Wire shall then be bent to the other side, and so forth, alternating to fracture. The minimum number of bends required is stated in the following table.

Wrapping Test.—A wrapping test is to be made on at least 10 per cent. of the total number of coils offered for inspection at one time. The wire is wrapped around its own diameter eight consecutive turns with a pitch substantially equal to the diameter of the wire and then unwrapped, maintaining the free end at approximately 90 degrees with the mandrel. It must stand this test without fracture. Because of the possibility of personal error in making this test, failure on one test is not considered conclusive, and if required to do so the inspector shall make at least one, but no more than two, additional tests on the sample of wire. If any of these tests are successful, the material shall be passed as satisfactory in this respect.

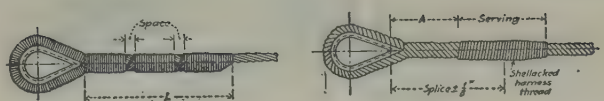
Selection of Test Specimen.—A tensile, a torsion and a bend test shall be made on each end of each piece or coil of wire. When an individual coil of wire is to be divided into smaller coils to meet special requirements, it is sufficient to make one test on the original coil and to cut and seal the small coils in the presence of the inspector.

ROUND HIGH-STRENGTH STEEL-WIRE TEST DATA

American Wire Gage	Diameter, Inches	Weight, Pounds per 100 Feet	Number of Bends through 90 Degrees	Breaking Strength, Minimum, Pounds	Tensile Strength, Pounds per Square Inch
6	0.162	7.01	5	4,500	219,000
7	0.144	5.56	6	3,700	229,000
8	0.129	4.40	8	3,000	233,000
9	0.114	3.50	9	2,500	244,000
10	0.102	2.77	11	2,000	244,000
11	0.091	2.20	14	1,620	254,000
12	0.081	1.744	17	1,300	252,000
13	0.072	1.383	21	1,040	255,000
14	0.064	1.097	25	830	258,000
15	0.057	0.870	29	660	259,000
16	0.051	0.690	34	540	264,000
17	0.045	0.547	42	425	267,000
18	0.040	0.434	52	340	270,000
19	0.036	0.344	70	280	275,000
20	0.032	0.273	85	225	280,000
21	0.028	0.216	105	175	284,000

Dimensions and Tolerances.—All wire for this purpose shall be furnished in decimal sizes corresponding to the American wire gage (Brown & Sharpe gage).

A permissible variation of 0.002 inch above gage on all sizes will be accepted, but no wire will be accepted having a variation of more than 0.0005 inch below gage.



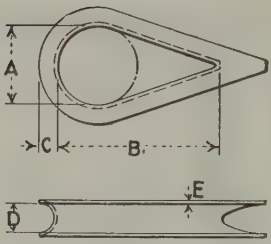
Aeronautic Steel Cable Loops
S. A. E., October, 1920

Non-Flexible Single-Strand Cable[1]							Flexible Multiple-Strand Cable[2]					
Diameter of Cable, Inches	Number of Strands	No. of Wires per Strand	Splice *L*, Inches	Space, Inches	Length of Loop Serving, Inches	Breaking Strength of Cable, Pounds	Number of Strands	No. of Wires per Strand	Length of Splice, Inches	Length of Serving, Inches	*A*, Inches	Breaking Strength of Cable, Pounds
1/16	1	19	1 1/2	1/8	1	500						
3/32	1	19	2	1/8	1 1/2	1,100	7	14	1 1/4	1	1/8	800
1/8	1	19	2 1/2	1/8	1 1/2	2,100	7	19	1 1/2	1	1/8	2,000
5/32	1	19	2 1/4	1/8	2	3,200	7	19	1 1/2	1 1/2	1/8	2,800
3/16	1	19	3	3/16	2 1/4	4,600	7	19	1 7/8	1 1/2	1/4	4,200
7/32	1	19	3 1/2	3/16	2 1/4	6,100	7	19	2 1/8	1 1/4	1/4	5,600
1/4	1	19	4	1/4	2 1/2	8,000						

[1] The loop portion is served with 0.0180 inch soft-steel tinned wire before thimble is inserted. The splice portion is served with 0.4010 inch soft-steel tinned wire, divided into three equal sections, as indicated in cut. The entire serving, including thimble and splice, must be soldered without drawing temper of wire.

[2] Number of tucks, three over core buried four under. The splice must be soldered full length, including thimble, without drawing temper of wire, then served with harness thread as shown and shellacked.

For thimble dimensions, see page 821.



AÈRONAUTIC STEEL THIMBLES

S. A. E., October, 1920

The thimbles must be galvanized either electrically or by the hot dip process.

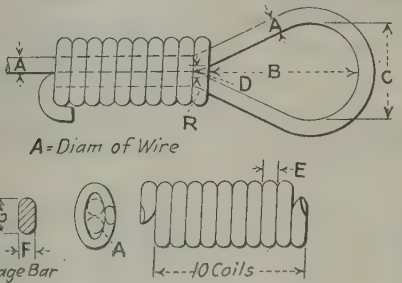
(Dimensions in Inches)

DIAMETER OF CABLE		A	B	C	D	E	Approx. Weight, Pounds per 1,000 Pieces
Nominal	Decimal						
1/16	0.062	0.35	0.70	0.07	0.09	0.032	3.00
3/32	0.094	0.35	0.70	0.07	0.09	0.032	3.00
1/8	0.125	0.35	0.70	0.07	0.13	0.032	4.34
5/32	0.156	0.40	0.80	0.10	0.17	0.032	6.36
3/16	0.187	0.50	1.00	0.135	0.21	0.032	9.00
7/32	0.219	0.60	1.20	0.15	0.24	0.032	13.50
1/4	0.250	0.70	1.40	0.17	0.25	0.032	16.63
9/32	0.281	0.80	1.60	0.198	0.30	0.040	30.36
5/16	0.312	0.90	1.80	0.21	0.33	0.040	33.00
3/8	0.375	1.00	2.00	0.26	0.39	0.060	74.00

Aeronautic Wire Loops and Ferrules

S. A. E., October, 1920

The loops for round tinned steel wire are made by threading the tension wire through a ferrule, forming a loop of the specified size, slipping the ferrule up against the loop and bending the free end of



the tension wire over the ferrule as shown. The ferrule is then thoroughly soldered in place without drawing the temper of the tension wire.

(Dimensions in Inches)

Round Wire Loops						Ferrule *E*		Gage Bar	
Size of Wire (*A*)		*B*	*C*	*D*	*R*	B. & S. Gage	Inches	*F*	*G*
B. & S. Gage	Inches								
8	0.128	$\frac{9}{16}$	$\frac{21}{64}$	$\frac{5}{16}$	$\frac{13}{64}$	9	0.114	0.130	0.260
8	0.128	$\frac{9}{16}$	$\frac{21}{64}$	$\frac{5}{16}$	$\frac{13}{64}$	9	0.114	0.130	0.260
10	0.102	$\frac{15}{32}$	$\frac{9}{32}$	$\frac{1}{4}$	$\frac{5}{32}$	11	0.091	0.104	0.208
12	0.081	$\frac{13}{32}$	$\frac{11}{64}$	$\frac{1}{4}$	$\frac{5}{32}$	13	0.072	0.083	0.166
14	0.064	$\frac{11}{32}$	$\frac{11}{64}$	$\frac{1}{4}$	$\frac{5}{32}$	15	0.057	0.066	0.132

Dimensions *A* and *E* are minima—tolerance, plus 0.002 inch. The gage bar has semicircular edges and shall pass through the ferrule with a clearance of approximately 0.003 inch.

Steel Bands and Strips

S. A. E. Standard, November, 1922

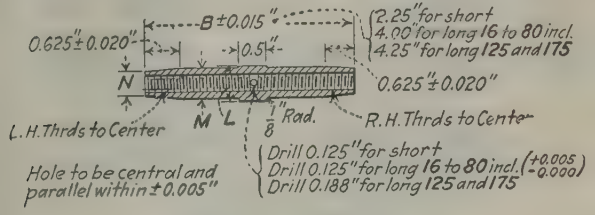
(Dimensions in Inches)

Width Varying by $\frac{1}{16}$ Inch		Thickness, B. W. G. No.	
From	To	From	To
	$\frac{3}{8}$	4 (0.238)	18 (0.049)
	$\frac{7}{16}$	4 (0.238)	19 (0.042)
$\frac{1}{2}$	1	4 (0.238)	23 (0.025)
$1\frac{1}{16}$	2	4 (0.238)	22 (0.028)
$2\frac{1}{16}$	3	1 (0.300)	21 (0.032)
$3\frac{1}{16}$	4	1 (0.300)	20 (0.035)
$4\frac{1}{16}$	$4\frac{1}{2}$	1 (0.300)	19 (0.042)
$4\frac{9}{16}$	$4\frac{3}{4}$	00 (0.380)	18 (0.049)
$4\frac{13}{16}$	$5\frac{1}{16}$	00 (0.380)	17 (0.058)
$5\frac{1}{8}$	$6\frac{3}{4}$	00 (0.380)	16 (0.065)
	7	1 (0.300)	14 (0.083)
	$7\frac{1}{2}$	1 (0.300)	14 (0.083)
	$7\frac{5}{8}$	1 (0.300)	14 (0.083)
	$7\frac{3}{4}$	1 (0.300)	14 (0.083)
	$7\frac{7}{8}$	1 (0.300)	14 (0.083)
	8	1 (0.300)	14 (0.083)
	$8\frac{1}{4}$	1 (0.300)	14 (0.083)
	$8\frac{1}{2}$	1 (0.300)	14 (0.083)
	$8\frac{5}{8}$	1 (0.300)	14 (0.083)
	$9\frac{5}{8}$	1 (0.300)	12 (0.109)

The Birmingham wire gage is used by the manufacturers of steel bands, hoops and strips. The thickness desired, however, should be expressed in thousandths of an inch when writing specifications for bands, hoops or strips.

TURNBUCKLES FOR AIRCRAFT

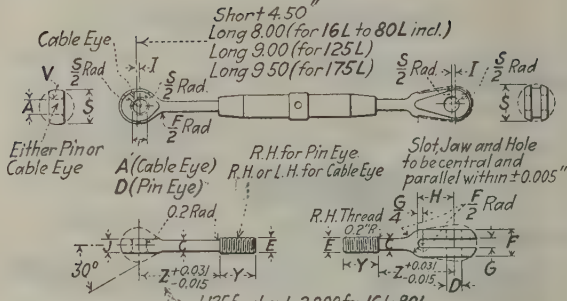
The following are standards adopted by Army and Navy Air Service and the S. A. E.



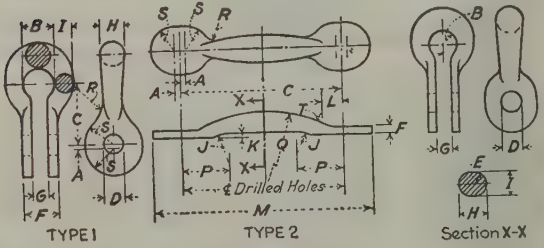
THREAD AND BARREL DIMENSIONS

No.	Strength, Pounds	Threads[1]	Pitch-Diameter Limits[1] in Inches		*L* ± 0.005, in Inches	*M* ± 0.005, in Inches	*N* ± 0.005, in Inches
			Max.	Min.			
8*S*	800	6–40	0.1235	0.1218	0.250	0.219	0.188
16*S* or *L*	1,600	10–32	0.1716	0.1697	0.375	0.281	0.250
21*S* or *L*	2,100	12–28	0.1950	0.1928	0.375	0.328	0.281
32*S* or *L*	3,200	1/4–28	0.2290	0.2268	0.438	0.391	0.328
46*S* or *L*	4,600	5/16–24	0.2878	0.2854	0.500	0.438	0.406
61*L*	6,100	3/8–24	0.3503	0.3479	0.625	0.594	0.469
80*L*	8,000	3/8–24	0.3503	0.3479	0.625	0.594	0.469
125*L*	12,500	5/16–20	0.4076	0.4050	0.750	0.688	0.563
175*L*	17,500	1/2–20	0.4701	0.4675	0.875	0.813	0.625

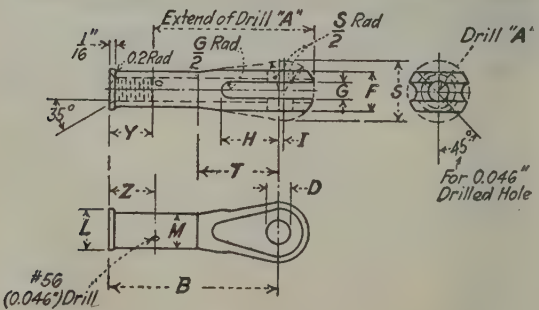
[1] Screw threads shall be in accordance with the Medium (Class 3). Fit for the Fine-Thread Series as specified in the American (National or S. A. E.) Standard for Screw-Thread.



Dimensions of Cable Eye, Pin Eye and Fork Ends



Cable Shackles



Rigid Terminals

Dimensions of Cable Eye, Pin Eye and Fork Ends

No.[1]	Strength, Pounds	Eye and Fork Ends, in Inches							Eye End, in Inches			Fork End, in Inches	
		C +0.006 −0.000	*D* +0.010 −0.000	*E*[2] Max.	*F* +0.010 −0.005	*I* +0.010 −0.000	*S*	*Y* ±0.047	*A* +0.010 −0.000	*J*	*V*	*G* +0.010 −0.000	*H*
8*S*	800	0.094	0.188	0.138	0.250	0.031	0.375	0.375	0.188	0.125	0.094	0.109	0.375
16*S* or *L*	1,600	0.133	0.188	0.190	0.313	0.031	0.500	0.500	0.219	0.188	0.172	0.150	0.469
21*S* or *L*	2,100	0.155	0.188	0.216	0.313	0.031	0.500	0.563	0.219	0.188	0.172	0.150	0.562
32*S* or *L*	3,200	0.189	0.250	0.250	0.438	0.047	0.625	0.625	0.281	0.219	0.203	0.203	0.625
46*S* or *L*	4,600	0.243	0.313	0.3125	0.500	0.047	0.688	0.750	0.313	0.281	0.250	0.203	0.625
61*L*	6,100	0.256	0.375	0.375	0.563	0.063	0.750	0.875	0.344	0.281	0.313	0.203	0.843
80*L*	8,000	0.306	0.375	0.375	0.563	0.063	0.875	0.875	0.375	0.328	0.375	0.266	0.875
125*L*	12,500	0.362	0.438	0.4375	0.719	0.078	0.063	1.000	0.469	0.375	0.453	0.344	1.000
175*L*	17,500	0.425	0.500	0.500	0.813	0.078	1.188	1.000	0.563	0.469	0.500	0.406	1.188

[1] This recommended practice is in agreement with Army-Navy Standards for Turnbuckles AN-44 to AN-50 adopted Nov. 1, 1924. The sizes are designated by the following key: *R*, right-hand thread; *L*, left-hand thread; *S*, short barrel; *L*, long barrel; 44, cable eye; 45, fork; 46, pin eye; 47 barrel; 48, turnbuckle assembly two cable eyes; 49, turnbuckle assembly with cable eye and fork; 50, turnbuckle assembly with cable eye and pin eye; *AN*, Army-Navy Standard. Thus *AN*-44-46*LL* indicates Army-Navy Standard long cable eye with a left-hand thread for a cable strength of 4,600 pounds.

[2] Screw threads shall be in accordance with the Medium (Class 3) Fit for the Fine-thread Series as Specified in the American (National or S. A. E.) Standard for Screw-Threads.

Cable Shackles

No.	Shackle and Cable Strength, Pounds	Shackle Type	D +0.010 −0.000	G +0.010 −0.000	F	S	I	H	A	B	C	R
8	800	1	0.188	0.109	0.250	0.250	0.172	0.172	0.031	0.250	0.563	0.375
16	1,600	1	0.188	0.150	0.313	0.250	0.172	0.172	0.031	0.250	0.563	0.375
21	2,100	1	0.188	0.150	0.313	0.281	0.172	0.172	0.031	0.250	0.563	0.375
32	3,200	1	0.250	0.203	0.438	0.313	0.219	0.250	0.031	0.375	0.750	0.438
46	4,600	1	0.313	0.203	0.500	0.375	0.219	0.281	0.063	0.438	0.813	0.500
61	6,100	1	0.375	0.203	0.563	0.375	0.281	0.313	0.063	0.500	0.875	0.500
80	8,000	2	0.375	0.266	0.148	0.406	0.375	0.438	0.063	0.219	2.750	0.406
125	12,500	2	0.438	0.360	0.179	0.531	0.469	0.594	0.094	0.313	4.000	0.750
175	17,500	2	0.500	0.406	0.203	0.625	0.563	0.688	0.125	0.313	4.250	0.500

Dimensions, which are in inches, apply to shackes after zinc plating. Tolerances are plus and minus 0.010 inch unless otherwise specified. Drill holes shall be central and parallel to tolerances of plus and minus 0.005 inch.

This recommended practice is in agreement with Army-Navy Standard *AN*-20 for Shackles adopted Nov. 1, 1924. The sizes are designated by "*AN*-20" and the number given in the above table, separated by a hyphen. For example, the *AN* number for the largest shackles is *AN*-20-175.

(Dimensions in Inches)

No.	Shackle Type	M	L	T	Q	P	J	K	E
80	2	3.688	0.281	0.250	2.000	0.719	0.500	0.078	0.188
125	2	5.250	0.375	0.250	3.500	1.125	0.625	0.125	0.250
175	2	5.750	0.375	0.500	3.375	1.250	1.000	0.109	0.297

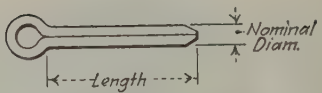
Rigid Terminals

No.	Wire Strength, Pounds	A		Pitch-Limits Diameter[2]		B	D	F	G	H	I	L	M	S	T	Y	Z
		Thread	Drill	Max.	Min.	±0.015	+0.010 −0.000	+0.010 −0.005	+0.010 0.000				+0.010 −0.000			±0.047	
10	1,000	6–40	0.147	0.1235	0.1218	1.313	0.188	0.250	0.109	0.375	0.031	0.313	0.250	0.375	0.625	0.250	0.313
21	2,100	10–32	0.199	0.1716	0.1697	1.532	0.188	0.313	0.150	0.469	0.031	0.375	0.281	0.500	0.719	0.313	0.375
34	3,400	1/4–28	0.261	0.2290	0.2268	1.813	0.250	0.438	0.203	0.625	0.047	0.438	0.375	0.625	0.875	0.438	0.500
46	4,600	5/16–24	0.323	0.2878	0.2854	1.875	0.313	0.500	0.203	0.625	0.047	0.500	0.438	0.688	0.875	0.563	0.625
61	6,100	3/8–24	0.323	0.2878	0.2854	2.000	0.375	0.563	0.203	0.843	0.063	0.500	0.453	0.750	1.000	0.563	0.625
80	8,000	7/16–24	0.386	0.3503	0.3479	2.250	0.375	0.563	0.266	0.875	0.063	0.563	0.547	0.875	1.125	0.688	0.750
115	11,500	1/2–20	0.453	0.4076	0.4050	2.500	0.438	0.719	0.344	1.000	0.078	0.687	0.625	1.063	1.250	0.750	0.813
155	15,500	1/2–20	0.516	0.4701	0.4675	2.813	0.500	0.813	0.406	1.188	0.078	0.750	0.703	1.138	1.438	0.875	0.938

Dimensions, which are in inches, apply to shackles after zinc plating. Tolerances are plus and minus 0.010 inch unless otherwise specified. Drill holes shall be central and parallel to tolerances of plus and minus 0.005 of an inch.

This recommended practice is in agreement with Army-Navy Standard *AN*-30 for Rigid Terminals adopted October, 1924. The sizes are designated by "*AN*-30" and the numbers given in the above table separated by a hyphen. For example, the *AN* number for the largest terminal is *AN*-30-155.

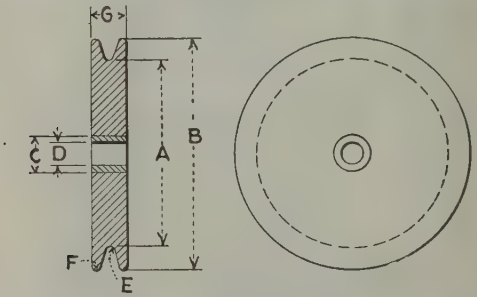
Screw threads shall be in accordance with the Medium (Class 3) Fit for the Fine-Thread Series as specified in the American (National or S. A. E.) Standard for Screw Threads.



BRASS COTTER PINS

No.	Nom. Diam. in Inches	Length, in Inches											Approx. Weight per Linear Inch, Pound
		2	3	4	5	6	7	8	10	12	14	16	
2	1/16	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	....	....	....	....	0.0011
3	3/32	1/2	3/4	1	1 1/4	1 1/2	1 1/2	2	....	....	....	....	0.0022
4	1/8	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/2	....	....	....	0.0045
5	5/32	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/2	....	....	....	0.0067
6	3/16	....	....	....	....	1 1/2	....	2	2 1/2	3	....	....	0.0101
8	1/4	....	....	....	....	....	....	2	2 1/2	3	3 1/2	4	0.0157

This recommended practice is in agreement with Army-Navy Standard *AN*-11 adopted Nov. 1, 1924. The sizes are designated by the Army and Navy by "*AN*-11," the cotter-pin size number given in the above table and the length designation, all separated by hyphens. For example, the *AN* number for the largest cotter-pin would be *AN*-11-8-16.



CABLE PULLEYS
(Dimensions in Inches)

No.[1]	Cable Size	*A*	*B*	*C*	*D* ±0.002	*E*	*F*	*G* ±0.015
1	1/16, 3/32	7/8	1 1/4	3/8	0.253	1/4	3/32	11/64
2	1/8, 5/32	2	2 1/2	3/8	0.253	1/4	1/8	11/64
3	3/16, 7/32, 1/4	1 3/4	2	1/2	0.378	1/4	1/8	1/16
4	5/16, 3/8, 7/16	2 1/8	3 1/2	1/2	0.378	1/4	1/8	1/16

Tolerances are plus and minus 0.010 inch unless otherwise specified.

This recommended practice is in agreement with Army-Navy Standard *AN*-21 for Shackles adopted Nov. 1, 1924. The sizes are designated by "*AN*-21" and the numbers given in the above table, separated by a hyphen. For example, the *AN* number for the largest pulley is *AN*-21-4.

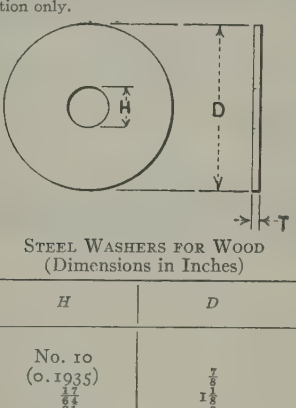
Cable Thimbles

Number[1]	A	B	C	D	E		Cable Diam.[2]	Approx. Weight,[2] Pounds
					Nom.	Tol.		
3	0.35	0.70	0.07	0.09	0.032	±0.003	$\frac{1}{16}$, $\frac{5}{64}$, $\frac{3}{32}$	0.0030
4	0.35	0.70	0.07	0.13	0.032	±0.003	$\frac{7}{64}$, $\frac{1}{8}$	0.0043
5	0.40	0.80	0.10	0.17	0.032	±0.003	$\frac{5}{32}$	0.0065
6	0.50	1.00	0.035	0.21	0.032	±0.003	$\frac{3}{16}$	0.0090
7	0.60	1.20	0.15	0.24	0.032	±0.003	$\frac{7}{32}$	0.0143
8	0.70	1.40	0.17	0.25	0.032	±0.003	$\frac{1}{4}$	0.0163
9	0.80	1.60	0.198	0.30	0.040	±0.004	$\frac{9}{32}$	0.0263
10	0.90	1.80	0.21	0.33	0.040	±0.004	$\frac{5}{16}$	0.0295
12	1.00	2.00	0.26	0.39	0.060	±0.004	$\frac{3}{8}$	0.0770

Dimensions, which are in inches, apply to timbles after zinc plating. Tolerances are plus or minus $\frac{1}{64}$ inch unless otherwise specified.

This recommended practice is in agreement with Army-Navy Standard AN19 for Thimbles adopted Oct. 14, 1924. The sizes are designated by "AN19" and the numbers given in the above table, separated by a hyphen. For example, the AN number for the largest thimble is AN19-12.

General information only.

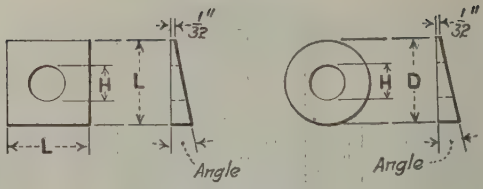


Steel Washers for Wood
(Dimensions in Inches)

No.	H	D	T
3	No. 10 (0.1935)	$\frac{7}{8}$	$\frac{1}{16}$
4	$\frac{17}{64}$	$1\frac{1}{8}$	$\frac{1}{16}$
5	$\frac{21}{64}$	$1\frac{3}{8}$	$\frac{1}{16}$
6	$\frac{25}{64}$	$1\frac{5}{8}$	$\frac{1}{16}$
7	$\frac{29}{64}$	$1\frac{13}{16}$	$\frac{1}{10}$
8	$\frac{33}{64}$	2	$\frac{1}{10}$
9	$\frac{37}{64}$	$2\frac{3}{16}$	$\frac{1}{8}$
10	$\frac{41}{64}$	$2\frac{3}{8}$	$\frac{1}{8}$

Tolerances are plus and minus 0.010 inch.

This recommended practice is in agreement with Army-Navy Standard AN-22 for Washers adopted Nov. 1, 1924. The sizes are designated by "AN-22" and the numbers given in the above table, separated by a hyphen. For example the AN number for the largest size would be AN-22-10.



BEVEL WASHERS, AERONAUTIC
S. A. E., October, 1920
(Dimensions in Inches)

Bolt Diam.	*H*	*D*	*L*
No. 4 (0.112)	No. 31 (0.120)	3/8	3/8
No. 6 (0.138)	No. 26 (0.147)	7/16	3/8
No. 8 (0.164)	No. 17 (0.173)	15/32	15/32
No. 10 (0.190)	No. 8 (0.199)	1/2	15/32
No. 12 (0.216)	No. 1 (0.228)	9/16	17/32
1/4	17/64	5/8	17/32
5/16	21/64	11/16	21/32
3/8	25/64	3/4	21/32
7/16	29/64	15/16	7/8
1/2	33/64	1	7/8

Angles: 6, 12, 24, 36 degrees for all sizes.
Faces shall be flat and free from burrs. Bright medium carbon steel shall be used.

RAILROAD SHOP DATA

Much information that applies to railroad shop work will be found in the various sections, as it seemed best to put only that which pertains solely to railroad shops under a separate heading.

TOOLS FOR BORING AND TURNING TIRES

Tire boring and turning practice varies on different railroads. There is a great variety of shapes and angles to the cutting edges. In most cases the rough boring tools have a rounded cutting edge of fairly large radius, while the finishing tools have a flat surface and smaller radius at the point. General data from 17 railroads are given in the following table:

TABLE 1.—CONDENSED TIRE BORING TOOL DATA

	Size of Tool Body, Inches	Top Rake of Tool, Degrees	Clearance at Point, Degrees	Cutting Speed Feet per Minute		Feed per Revolution	
				Roughing	Finishing	Roughing	Finishing
1	1 × 2	12	15	18	18	$\frac{1}{4}$	$\frac{1}{4}$
2	$1\frac{1}{2}$ × $1\frac{1}{2}$	8	6	25	25	$\frac{1}{4}$	$\frac{1}{2}$
3	$1\frac{1}{2}$ × $1\frac{1}{2}$	12	10	15	15	$\frac{1}{2}$	$\frac{1}{2}$
4	1 × $1\frac{1}{2}$	6	6	14	12	$\frac{1}{8}$	$\frac{1}{8}$
5	$1\frac{1}{4}$ × $1\frac{1}{4}$	6	7	16	16	$\frac{1}{16}$	$\frac{1}{2}$
6	$1\frac{1}{4}$ × $1\frac{1}{4}$	8	6	16	$20\frac{1}{2}$	$\frac{3}{32}$	$\frac{3}{32}$
7	$1\frac{1}{4}$ × $1\frac{1}{4}$	8	5	26	26	$\frac{5}{16}$	$\frac{5}{16}$
8	$1\frac{1}{4}$ × $1\frac{1}{4}$	18	5	23	23	$\frac{5}{32}$	$\frac{5}{16}$
9	$1\frac{1}{4}$ × $1\frac{1}{4}$	8–10	7	40	40	$\frac{1}{8}$	$\frac{1}{8}$
10	$1\frac{1}{2}$ × 2	7	8	12–20	12–20	$\frac{1}{4}$	$\frac{1}{4}$
11	1 × 1	4	6	18	18	$\frac{1}{8}$	$\frac{1}{8}$
12	1 × 2	5	7	55	50	$\frac{1}{8}$	$\frac{3}{8}$
13	$1\frac{1}{2}$ × $1\frac{3}{4}$	4	$4\frac{1}{2}$	24	24	$\frac{1}{8}$	$\frac{1}{4}$
14	1 × 1	15	6	28	28	$\frac{1}{16}$	$\frac{1}{16}$
15	$1\frac{1}{4}$ × $1\frac{1}{4}$	2	7	$19\frac{3}{4}$	$19\frac{3}{4}$	$\frac{5}{16}$	$\frac{5}{16}$
16	$1\frac{1}{2}$ × 3	6	4	30	30	$\frac{1}{16}$	$\frac{1}{16}$
17	$1\frac{1}{4}$ × $1\frac{1}{4}$	2	7	30	30	$\frac{3}{8}$	$\frac{3}{8}$

A few of the typical shapes are shown in Fig. 1.

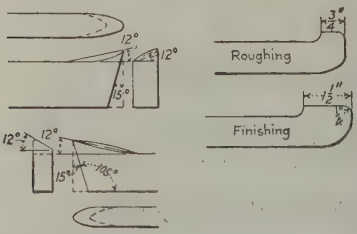


FIG. 1.—Tire Boring Tools

TIRE TURNING

Tires are rough turned with coarse feed, occasionally as much as $\frac{1}{2}$ inch per revolution when the lathe will stand such a cut. Some contend that this is not economical on account of the amount of metal left for the form-finishing tool. The roughing tools usually have a round nose and top rakes as shown in Table 2.

TABLE 2.—TIRE TURNING DATA

	Size of Tool Body in Inches	Top Rake of Tool, Degrees	Clearance at Point, Degrees	Cutting Speed, Feet per Minute		Feed per Revolution in Inches, Roughing
				Roughing	Finishing	
1	$1\frac{1}{2} \times 2\frac{1}{2}$	10	5	10–15	10–15	$\frac{1}{4}$–$\frac{3}{8}$
2	$2\frac{1}{2} \times 2\frac{1}{2}$	5	$3\frac{1}{2}$	17	17	
3	2×3	12	15	16–18	18	
4	$1\frac{1}{2} \times 3$	2	4	11	11	$\frac{1}{4} \times \frac{3}{8}$
5	$1\frac{1}{2} \times 3$	8	6	16	12	
6	$1\frac{1}{2} \times 3$	4–6	6–8	13	13	
7	$1\frac{1}{2} \times 3$	6	6	15	17	
8	$1\frac{1}{2} \times 2\frac{1}{2}$	5	5	12	12	$\frac{5}{16}$
9	$1\frac{1}{2} \times 2\frac{1}{2}$	8	6	17	17	
10	$1\frac{1}{2} \times 3$	5	5	15	15	
11	2×3	5	5	13 7	13 7	
12	$1\frac{1}{2} \times 2$	2–3	7	14	14	
13	2×3	7	8	12–20	12–20	
14	$2 \times 2\frac{1}{4}$	6	6	16	16	
15	$1\frac{1}{2} \times 4$	2	7	50	45	
16	$1\frac{1}{2} \times 1\frac{3}{4}$	11	4	14–18	14–18	$\frac{5}{16}$
17	$1\frac{1}{2} \times 3$	12	6	15	10	$\frac{5}{16}$
18	$1\frac{1}{2} \times 3$	3	5	$13\frac{3}{4}$	$12\frac{1}{2}$	
19	$1\frac{1}{2} \times 3$	2	5	18	12	
20	$1\frac{1}{2} \times 3$	2	5	15	17	

Flanged tires are finished with tools that must conform to A. R. A. standards (formerly the Railway Master Mechanics), as outlined in Fig. 4. The form tools must be made in pairs, for right and left wheels. They are usually made in two parts, one to form the flange and part of the tread, while the other tool forms the rounded edge and the rest of the tread—as *A* and *B* in Fig. 3.

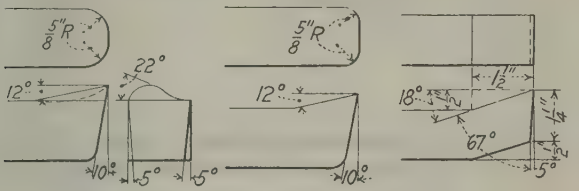


FIG. 2.—Tire Turning Tools

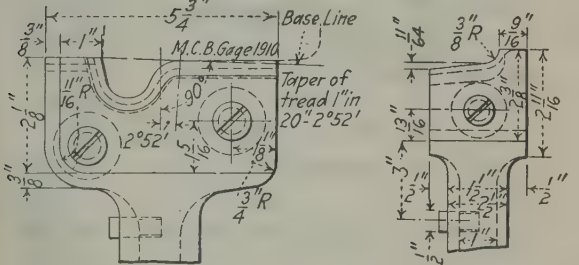
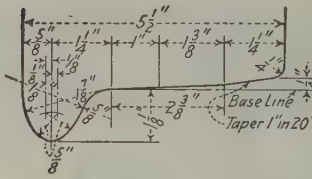


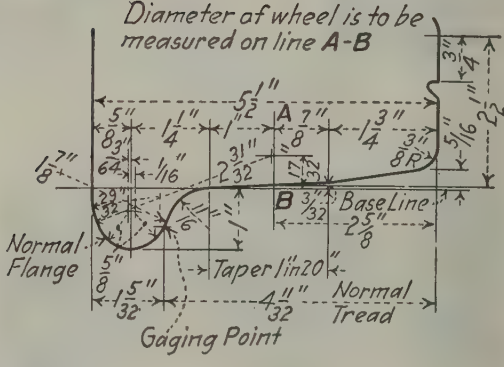
FIG. 3.—Form Tools for Flanges

STANDARD SECTION OF TIRES

Adopted, 1893; Revised, 1912, by the Master Car Builders, Master Mechanics of the Mechanical Division American Railway Association. Outlines and dimensions are on page 826.



(*a*)



(*b*)

FIG. 4.—Standard Flanged Tire. (*a*) Driving wheel tire. (*b*) Trailing wheel tire

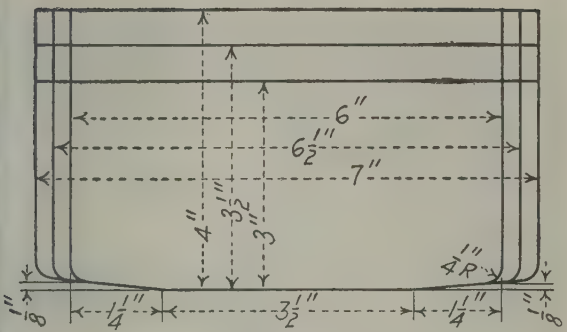


FIG. 5.—Standard Plain Tire

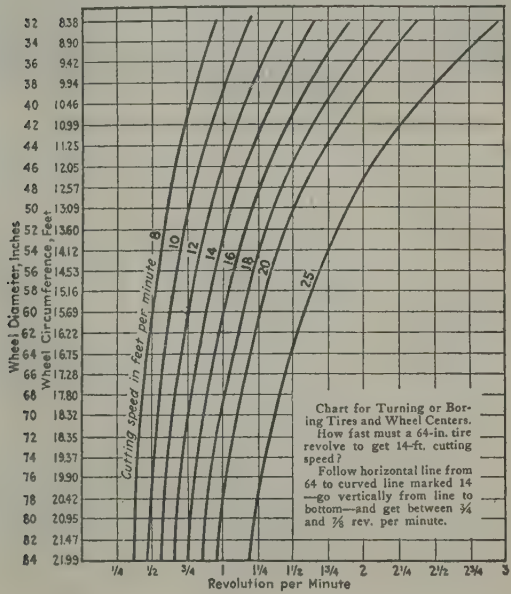


FIG. 6.—Chart for Tire Turning Speeds

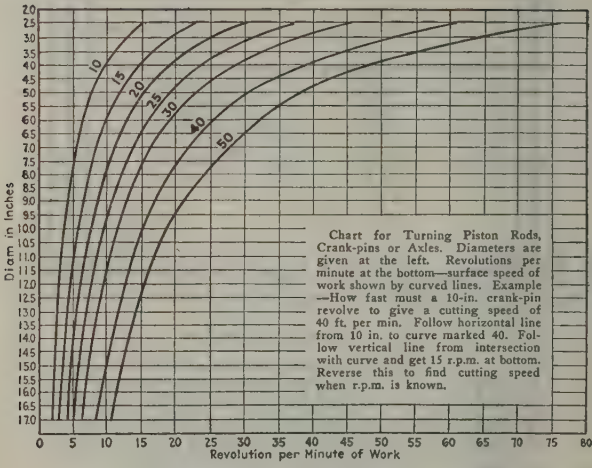


FIG. 7.—Chart for Turning Crank Pins, Axles, Etc.

Minimum Thickness for Driving Wheel and Trailer Tires on Standard and Narrow-gage Locomotives

Weight per Axle (Weight on Drivers Divided by Number of Pairs of Driving Wheels)	Diameter of Wheel Center in Inches	Minimum Thickness, Service Limits in Inches	
		Road Service	Switching Service
30,000 pounds and under	44 and under	1 1/2	1 1/2
	Over 44 to 50	1 5/16	1 3/16
	Over 50 to 56	1 1/2	1 1/2
	Over 56 to 62	1 7/16	1 3/16
	Over 62 to 68	1 1/2	
	Over 68 to 74	1 9/16	
	Over 74	1 5/8	
Over 30,000 to 35,000 pounds	44 and under	1 5/16	1 3/16
	Over 44 to 50	1 5/8	1 1/2
	Over 50 to 56	1 7/16	1 5/16
	Over 56 to 62	1 1/2	1 5/8
	Over 62 to 68	1 9/16	
	Over 68 to 74	1 5/8	
	Over 74	1 11/16	
Over 35,000 to 40,000 pounds	44 and under	1 3/8	1 1/2
	Over 44 to 50	1 7/16	1 5/16
	Over 50 to 56	1 1/2	1 5/8
	Over 56 to 62	1 9/16	1 7/16
	Over 62 to 68	1 5/8	
	Over 68 to 74	1 11/16	
	Over 74	1 3/4	
Over 40,000 to 45,000 pounds	44 and under	1 7/16	1 5/8
	Over 44 to 50	1 1/2	1 3/8
	Over 50 to 56	1 9/16	1 7/16
	Over 56 to 62	1 5/8	1 1/2
	Over 62 to 68	1 11/16	
	Over 68 to 74	1 3/4	
	Over 74	1 13/16	
Over 45,000 to 50,000 pounds	44 and under	1 1/2	1 3/8
	Over 44 to 50	1 9/16	1 7/16
	Over 50 to 56	1 5/8	1 1/2
	Over 56 to 62	1 11/16	1 9/16
	Over 62 to 68	1 3/4	
	Over 68 to 74	1 13/16	
	Over 74	1 7/8	
Over 50,000 to 55,000 pounds	44 and under	1 9/16	1 7/16
	Over 44 to 50	1 5/8	1 1/2
	Over 50 to 56	1 11/16	1 9/16
	Over 56 to 62	1 3/4	1 5/8
	Over 62 to 68	7 13/16	
	Over 68 to 74	1 7/8	
	Over 74	1 15/16	
Over 55,000 pounds	44 and under	1 5/8	1 1/2
	Over 44 to 50	1 11/16	1 9/16
	Over 50 to 56	1 3/4	1 5/8
	Over 56 to 62	1 13/16	1 11/16
	Over 62 to 68	1 7/8	
	Over 68 to 74	1 15/16	
	Over 74	2	

—*American Locomotive Company.*

Shrinkage of Tires on Wheels
(Dimensions in Inches)

M. M. Standard, 1908. Shrinkage $\frac{1}{80}$ inch per foot for 38-inch centers, $\frac{1}{60}$ inch per foot for 90-inch centers, increasing uniformly between these limits. M. M. Standard center diameters are shown in heavy type.

Center	Tire		Center	Tire		Center	Tire	
Exact Diam.	Shrinkage	Exact Bore	Exact Diam.	Shrinkage	Exact Bore	Exact Diam.	Shrinkage	Exact Bore
20	.021	19.979	40	.042	39.958	60	.071	59.929
21	.022	20.978	41	.044	40.956	61	.073	60.927
22	.023	21.977	42	.045	41.955	**62**	.075	61.925
23	.024	22.976	43	.046	42.954	63	.076	62.924
24	.025	23.975	**44**	.048	43.952	64	.078	63.922
25	.026	24.974	45	.049	44.951	65	.079	64.921
26	.027	25.973	46	.050	45.950	**66**	.081	65.919
27	.028	26.972	47	.052	46.948	67	.083	66.917
28	.029	27.971	48	.053	47.947	68	.084	67.916
29	.030	28.970	49	.055	48.945	69	.086	68.914
30	.031	29.969	**50**	.056	49.944	**70**	.088	69.912
31	.032	30.968	51	.058	50.942	71	.090	70.910
32	.033	31.967	52	.059	51.941	**72**	.091	71.909
33	.034	32.966	53	.060	52.940	73	.093	72.907
34	.035	33.965	54	.062	53.938	**74**	.095	73.905
35	.036	34.964	55	.064	54.936	75	.097	74.903
36	.038	35.962	**56**	.065	55.935	76	.098	75.902
37	.039	36.961	57	.067	56.933	77	.100	76.900
38	.040	37.960	58	.068	57.932	**78**	.102	77.898
39	.041	38.959	59	.070	58.930	79	.014	78.896

—American Locomotive Company.

Fig. 8 shows shrink dimensions in a condensed form.

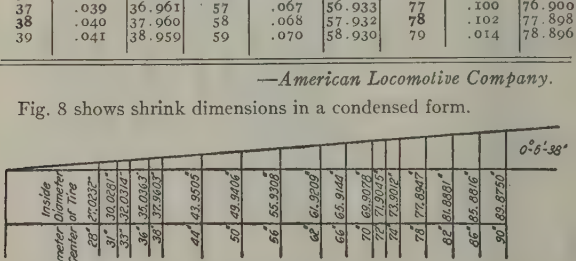


Fig. 8.—Diagram of Shrink Fits

SHIMS FOR LOCOMOTIVE TIRES

While tires should be fitted without shims whenever possible, they are permitted by the Interstate Commerce Commission for old tires. On driving wheels they should be approximately the full width of the tire. The Santa Fe gives $5\frac{1}{4}$ inches as width for drivers and thicknesses varying from No. 31 B. W. G. or 0.010 to $\frac{1}{4}$ inch. The shrinkage, with shims, is $\frac{1}{64}$ inch per foot of diameter of wheel center. Tires should cool gradually after shrinking.

Allowances for Boring Tires for Driving Wheels—Southern Pacific Company
(Dimensions in Inches)

Nominal Outside Diam.	Diam. of Wheel Center	Diam. to Bore Tire	Nearest 64th	Allowance for Shrinking of Tire
45	38	37.9603	$37\frac{31}{32}$	0.0397
51	44	43.9505	$43\frac{61}{64}$	0.0495
55	48	47.9500	$47\frac{61}{64}$	0.0500
57	50	49.9406	$49\frac{15}{16}$	0.0594
63	56	55.9308	$55\frac{59}{64}$	0.0692
69	62	61.9209	$61\frac{59}{64}$	0.0791
73	66	65.9144	$65\frac{29}{32}$	0.0854
77	70	69.9078	$69\frac{29}{32}$	0.0922
79	72	71.9045	$71\frac{29}{32}$	0.0955
81	74	73.9012	$73\frac{29}{32}$	0.0988
84	78	77.8947	$77\frac{57}{64}$	0.1053

Press Fits of Axles and Crank Pins
cast-steel or rolled-steel wheel centers

Diam. of Axle or Crank Pin, in Inches	Bore of Hole in Inches	Pressure Required in Tons	Diam. of Axle or Crank Pin in Inches	Bore of Hole in Inches	Pressure Required in Tons
$2\frac{1}{2}$	2.489	28–37	$7\frac{1}{2}$	7.478	83–112
3	2.988	33–45	8	7.977	88–120
$3\frac{1}{2}$	3.486	38–52	$8\frac{1}{2}$	8.477	94–127
4	3.984	44–60	9	8.976	99–135
$4\frac{1}{2}$	4.483	50–67	$9\frac{1}{2}$	9.476	105–142
5	4.982	55–75	10	9.975	110–150
$5\frac{1}{2}$	5.481	61–82	$10\frac{1}{2}$	10.475	115–157
6	5.979	66–90	11	10.975	121–165
$6\frac{1}{2}$	6.479	72–97	$11\frac{1}{2}$	11.474	126–172
7	6.978	77–105	12	11.976	132–180

for cast-iron wheel centers

$2\frac{1}{2}$	2.491	18–22	$7\frac{1}{2}$	7.480	53–67
3	2.990	21–27	8	7.979	56–72
$3\frac{1}{2}$	3.488	24–31	$8\frac{1}{2}$	8.479	60–76
4	3.986	28–36	9	8.978	63–80
$4\frac{1}{2}$	4.485	32–40	$9\frac{1}{2}$	9.478	67–85
5	4.984	35–45	10	9.977	70–90
$5\frac{1}{2}$	5.482	39–49	$10\frac{1}{2}$	10.477	74–94
6	5.981	42–54	11	10.977	77–99
$6\frac{1}{2}$	6.481	46–58	$11\frac{1}{2}$	11.476	81–103
7	6.980	49–63	12	11.976	84–108

PRESSURE FOR FORCING PISTON RODS INTO PISTON HEADS

Diameter of Rod in Inches	Pressure in Tons	Diam. of Rod in Inches	Pressure in Tons	Diameter of Rod in Inches	Pressure in Tons
$2\frac{1}{2}$	30–40	$3\frac{1}{4}$	40–50	$4\frac{1}{4}$	55–65
$2\frac{3}{4}$	30–40	$3\frac{1}{2}$	45–55	$4\frac{1}{2}$	55–65
3	35–45	$3\frac{3}{4}$	45–55	$4\frac{3}{4}$	60–70
		4	50–60	5	65–75

Pressures must be obtained before collar reaches its seat, and collar must in all cases seat solidly on piston head.

—*American Locomotive Company.*

STANDARD AMERICAN RAILWAY ASSOCIATION WHEEL CIRCUMFERENCE MEASURE FOR CAST-IRON CAST-STEEL, WROUGHT-STEEL AND STEEL-TIRED WHEELS

Adopted, 1893; Modified, 1919

Instructions for Using Standard Wheel Circumference Measure for Steel, Steel-Tired and Cast-Iron Wheels

Place tape about circumference of wheel, having the brackets in contact with flange. The normal circumference for wheels of each of the different diameters is indicated by the space marked "3." Steel and steel-tired wheels should be rejected if the scribed lines on the head piece fall to the left of the space marked "C" or to the right of the space marked "$\frac{1}{2}$." Cast-iron wheels should be rejected if the scribed line on the head piece falls to the left of the space marked "1" or to the right of the space marked "5."

The continuous markings on the upper side of the tape may be used for mating worn wheels.

The tape and method of using is shown in Fig 9.

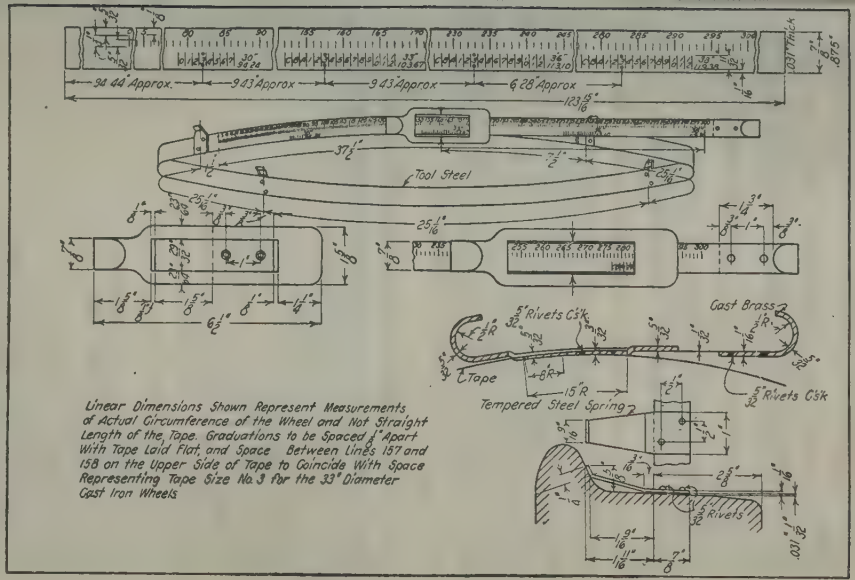


FIG. 9.—Wheel Measuring Tape and Its Use

FITS USED IN LOCOMOTIVE REPAIR WORK

The Heald Machine Company gives the following suggestions for running fits in railway shop work, based on observations in many localities

Valve motion pins or bolts and bushings, 0.003 to 0.006 inch.

Side rod knuckle pins and bushings, 0.005 to 0.008 inch.

Crank pins and rod bushings 6 inches or less in diameter, 0.010 to 0.015 inch.

Crank pins and rod bushings over 6 inches in diameter, 0.015 to 0.020 inch.

Driver axles and driver boxes, 0.015 to 0.025 inch.

Piston rod and metallic packing, 0.001 to 0.003 inch.

Piston rod allowable variation in diameter from end to end, 0.002 inch.

Air pump piston rods, allowable variation in diameter from end to end, 0.001 inch.

One method of repairing motion work is to true up the hole in the lever and then grind the outside of the bushing 0.004 inch larger than the hole. The hole in the bushing is ground 0.008 inch larger than the pin. Forcing the bushing in the lever reduces the hole to about 0.004 inch for an oil film.

Brass cylinder bushings in triple valves require careful attention. When the difference in diameter between the two ends exceeds 0.002 inch the bushing should be reground just enough to remove the worn spots.

TAPER FITS USED IN LOCOMOTIVE WORK

There are several different tapers used in locomotive work, the tapers varying from $\frac{1}{16}$ to $1\frac{1}{2}$ inches to the foot. The Santa Fé system has adopted the following standards:

Taper of $\frac{1}{16}$ inch in 12 inches for:
- Bolts for main and side rods.
- Bolts for engine frames.
- Eccentric splice bolts.
- Eccentric crank bolts.
- Long reverse-yoke pin in Baker valve gear.

Taper of $\frac{3}{8}$ inch in 12 inches for:
- Bell-crank pin.
- Combination-lever pin—long.
- Link-block pin.
- Reverse-shaft hanger pins, Stephenson gear.
- Rocker-arm pins in single shear.
- Valve-stem sockets.

Taper of $\frac{1}{2}$ inch in 10 inches for:
- Combination-lever pin—short.
- Connecting-rod pin—top and bottom.
- Connecting-rod pin bushing—center.
- Eccentric-rod pins.
- Piston-rod fit in cross-head.
- Piston-rod fit in spider.
- Reach-rod pins.

Reverse-shaft hanger pins—Walschaert gear.
Reverse-yoke pin—short—Baker gear.
Reverse-gear piston fit in spider and in cross-head.
Radius-bar pin.
Rocker-arm pins in double shear.
Union link pins.
Valve-rod knuckle joint pins.
Valve-rod pins.
Valve-stem cross-head pin.

A taper of $\frac{3}{4}$ inch in 12 inches is used for the eccentric-blade pins and of $\frac{3}{4}$ inch in 10 inches for the center connecting-rod pin.

A taper of $1\frac{1}{2}$ inch in 12 inches is used for crown-bar bolts where they fit in the crown sheet. The same taper is used for side-rod knuckle joint pins.

TAPER THREADS IN LOCOMOTIVE WORK

Nearly all taper threads used in railway work are of the standard pipe-thread taper of $\frac{3}{4}$ inch in 12 inches or 1 inch in 16 inches. The diameters, however, do not conform to standard pipe sizes and 12 threads to the inch is usual regardless of diameter. On the Santa Fé system threads of 6, 9, 10 and 11 per inch are used in some cases.

MACHINING ROD ENDS

Milling is replacing slotting for machining rod ends. In solid-end rods the block is removed either with the oxyacetylene torch or by drilling a hole large enough for a helical milling cutter to go through. In some cases a hole is drilled for starting the torch cut but is not necessary as a hole can be burned through a 4-inch piece in less than 30 seconds. Milling out the block from the solid can be done at from $\frac{3}{8}$ to $\frac{7}{8}$ inch per minute depending on the diameter of the cutter and the thickness of the rod. The $\frac{3}{8}$ inch feed is for a rod 7 inches thick. For finishing, the cut, whether block is milled out or burned out, usually varies from 3 to $5\frac{1}{2}$ inches per minute.

SHOP TRIGONOMETRY

THE laying out of angles is sometimes difficult by ordinary methods and a little knowledge of shop "trig" is very useful and much easier than if it were called by its full name.

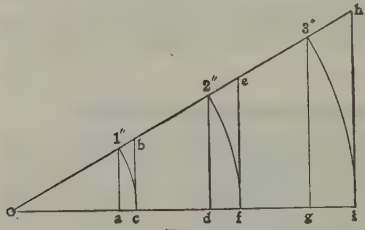


FIG. 1

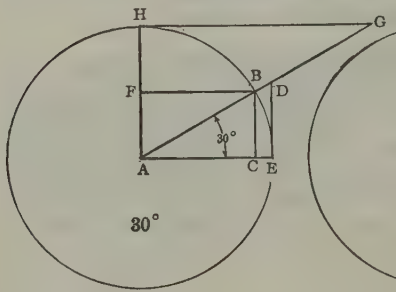


FIG. 2

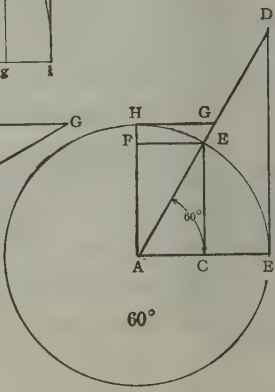


FIG. 3

It is really a system of constants or multipliers based on the fact that there are always fixed proportions between the sides and angles of triangles and other figures. Fig. 1 shows a 30-degree angle with 1, 2 and 3-inch arcs, 1 *c*, 2 *f*, and 3 *i*. It will be found that every similar measurement is in exact proportion to the radius, thus 2 *d* is exactly twice the length of 1 *a*, and *h i* is just three times *b c*. So, if we know the distance *a c* for a 1-inch radius for any angle, a similar distance, as *g i* for the same angle, will be in exact proportion to the radius of the circle to one, which is the base. All these parts are named as shown in Figs. 2, 3, and 4.

The exact proportions of all the various parts have been figured for each part of a degree that is likely to be needed in ordinary work, and these figures are given in the tables which follow. These numbers are simply multipliers or constants for a radius of one, and for any other radius we multiply the numbers given by the radius we are using. These tables form the most accurate means of calculating many problems as will be shown. These constants can represent *one* of anything, inches, feet, meters, or miles, and the answer will be in the same unit. In tool work they are usually in inches, but the relation is the same regardless of the unit.

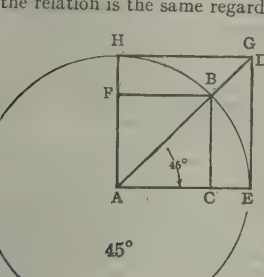


FIG. 4

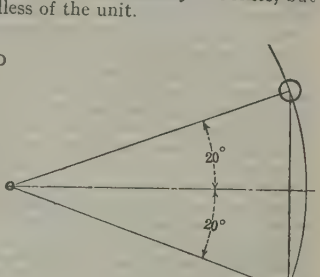


FIG. 5

ANGLE IS ALWAYS TAKEN EACH SIDE OF THE CENTER LINE AS SHOWN

Lines A–E and A–H are called radius of the circle.
A–C is called cosine of the angle.
F–B is always the same as cosine of the angle.
C–E is called the versed sine of the angle.
F–H " " " co-versed sine of the angle.
C–B " " " sine " " "
E–D " " " tangent " " "
H–G " " " co-tangent " " "
A–D " " " secant " " "
A–G " " " co-secant " " "

The names always refer to the angle on one side of the center ne and not to the total or included angle. In dealing with a 60-egree thread we divide this by a center line and call the angle 30 egrees in all our calculations. Everything is based on the radius a circle, and a 1 radius is used as this base. Perhaps the three ost important parts are the *sine*, the *tangent*, and the *secant*, these eing C–B, E–D, and A–D in all three of the figures. From this it ll be seen that the sine is half the chord or the distance from the dius to the horizontal. The tangent E–D is the distance from e horizontal radius to an extension of the radius at the angle given.

The secant is the distance along the radius from the center to the tangent. From *C* to *E* is called the *versed sine*, and is the distance from the center of the chord to the outer circle.

The angle considered in this work is always less than 90 degrees, and the angle between the angle used and 90 degrees, or the angle which is necessary to complete this to 90 degrees is called the complementary angle. In the first case the complementary angle is 60 degrees, in the second case 30 degrees, and in the third case 45 degrees. The *cosine* is the distance *F–B*, the *co-tangent* is *H–G*, the *co-secant* is *A–G*, and the *co-versed sine* is *F–H* in all three examples. In the 45-degree angle it will be seen that the various parts are alike in both angles, as the sine is the same as the cosine, while the sine of the angle of 30 degrees is the same as the cosine of the angle of 60 degrees. These facts will be borne out by the tables and can be seen by studying the diagrams or by making any calculation and then proving it as near as may be on the drawing board.

All this is interesting, but unless it is useful it has no value to the practical man, so we will see where it can be used to advantage in saving time and labor.

Perhaps the easiest application is in finding the depth of a V-thread without making any figures. The angle is 60 degrees or 30 degrees each side of the center line. The pitch is 1 inch so that each side is also an inch, and so the radius is an inch, the depth of the thread is the distance *A–C* or *F–B*, and is the cosine of the angle. Looking in the table for the cosine of the angle of 30 degrees we find 0.86603, and as the radius is 1 this gives us the depth directly as 0.86603 inch. If the radius was 2 inches we would multiply by 2, or if it was $\frac{1}{2}$ inch, divide by 2 and get the exact depth with almost no figuring. Suppose, on the other hand, that the thread was 1 inch deep and we want to find the length of one side, the angle remaining the same as before. In this case we have the depth which is the line *A–E*, and we wish to find *A–D* which is the secant, so we look at the table again and find the secant of 30 degrees to be 1.1547 inches as the length of the side.

Suppose you have a square bar $2\frac{1}{2}$ inches on each side, what is the distance across the corners? Looking at the second example we see that the side of the square bar is represented by line *A–E* and the corner distance by the secant *A–D* so we look for the secant of 45 degrees (because we know that half the 90-degree angle of a square bar must be 45 degrees) and find 1.4142 which would be the distance if the bar was 1 inch square, so we multiply 1.4142 by $2\frac{1}{2}$ and get 3.5355 inches as the distance across the corners, and can know that this is closer than we can measure, and is not a guess by any means.

Reversing this we can find the side of a square that can be milled out of a round bar, such as the end of a reamer or tap. What square can we make on a 2-inch round reamer shank? The diameter of the bar is the radius as *A–B* and the angle 45 degrees as before, half the side of the square will be the sine *C–B*, which the table shows to be 0.70711, and as this is half the chord which makes the flat across the bar, we multiply this by 2 and get 1.41422 inches as the distance across the flats for a reamer shank of this size.

Suppose we have a bar of $1\frac{1}{2} \times \frac{3}{4}$-inch steel and want to find the distance across the corners, and the angle it will make with the base. The $1\frac{1}{2}$-inch side is the radius, the diagonal is the secant, and the $\frac{3}{4}$-inch side is the tangent of the angle. Reducing these to a basis of 1 inch we have a bar 1 inch by $\frac{1}{2}$ inch and the $\frac{1}{2}$ inch is the tangent of the angle. Looking in the table we find this to be almost

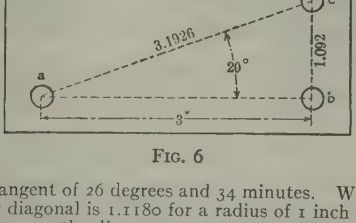


FIG. 6

exactly the tangent of 26 degrees and 34 minutes. With this angle the secant or diagonal is 1.1180 for a radius of 1 inch and $1\frac{1}{2}$ times this gives 1.6770 as the distance across corners.

A very practical use for this kind of calculation is in spacing bolt holes or otherwise dividing a circle into any number of equal parts.

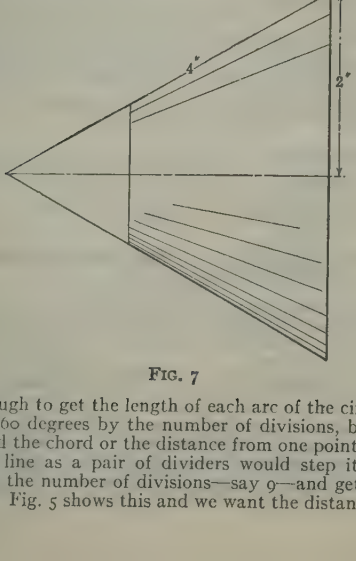


FIG. 7

It is easy enough to get the length of each arc of the circumference by dividing 360 degrees by the number of divisions, but what we want is to find the chord or the distance from one point to the next as a straight line as a pair of dividers would step it off. First divide 360 by the number of divisions—say 9—and get 40 degrees for each part. Fig. 5 shows this and we want the distance shown or

the chord of the angle. This equals twice the sine of half the angle. Half the angle is 20 degrees and the sine for this is 0.342. Twice this or 0.684 is the chord of the 40-degree angle for every inch of radius If the circle is 14 inches in diameter the distance between the holes will be 7 times 0.684 or 4.788 inches. This is very quick and the most accurate method known.

Draftsmen often lay out jigs with the angles marked in degrees as in Fig. 6, overlooking the fact that the toolmaker has no convenient or accurate protractor for measuring the angle. Assume that a drawing shows three holes as a, b, and c, with b and c 20 degrees apart. The distance from a to b is 3 inches, what is the distance from b to c or from a to c?

As the known radius is from a to b, the distance $b\,c$ is the tangent of the angle and the tangent for a 1-inch radius is 0.36397, so for a 3-inch radius it is $3 \times 0.36397 = 1.09191$ inches from b to c and at right angles to it.

But we need not depend on the accuracy of the square or of the way we use it, as we can find the distance from a to c just as easily and just as accurately as we did $b\,c$. This distance is the secant and is 1.0642 for a 1-inch radius. Multiplying this by $3 = 3.1926$ as the distance which can be accurately measured.

If the distance between a and c had been 3 inches, then $b\,c$ would have been the sine and $a\,b$ the cosine of the angle, both of which can be easily found from the tables.

It often happens that we want to find the angle of a roller or other piece of work as Fig. 7. Always work from the center line and continue the lines to complete the angle. Every triangle has the sides and they are called the "side opposite," "side adjacent," and "hypotenuse," the first being opposite the angle, the second the base line, and the third the slant line.

The following rules are very useful in this kind of work:

(1) $\text{Sine} = \dfrac{\text{Side Opp.}}{\text{Hypot.}}$

(2) $\text{Cosine} = \dfrac{\text{Side Adj.}}{\text{Hypot.}}$

(3) $\text{Tangent} = \dfrac{\text{Side Opp.}}{\text{Side Adj.}}$

(4) $\text{Cotangent} = \dfrac{\text{Side Adj.}}{\text{Side Opp.}}$

(5) $\text{Hypot.} = \dfrac{\text{Side Opp.}}{\text{Sine.}}$

(6) Side Opp. = Hypot. × Sine.

(7) Side Adj. = Hypot. × Cosine.

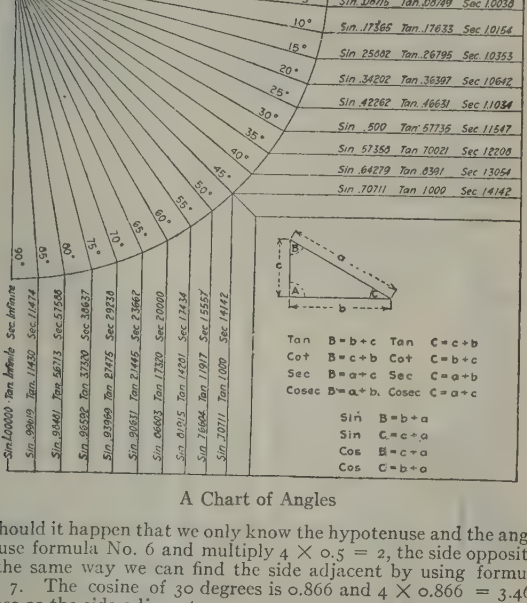
(8) Side Opp. = Side Adj. × Tangent.

(9) Side Adj. = Cotan. × Side Opp.

(10) $\text{Hypot.} = \dfrac{\text{Side Adj.}}{\text{Cosine.}}$

If we have the dimensions shown in Fig. 7, the side opposite and the hypotenuse, we use formula No. 1, and dividing 2 by 4 we get $\frac{1}{2}$ or 0.5 as the sine of the angle. The table shows this to be the sine of the angle of 30 degrees, consequently this is a 30-degree angle.

If we have the side opposite and the side adjacent we use formula No. 3, and find that $\frac{2}{4} = \frac{1}{2}$ or .5 = the tangent of the angle. The table shows this to be the tangent of 26 degrees and 34 minutes.



A Chart of Angles

Should it happen that we only know the hypotenuse and the angle we use formula No. 6 and multiply $4 \times 0.5 = 2$, the side opposite. In the same way we can find the side adjacent by using formula No. 7. The cosine of 30 degrees is 0.866 and $4 \times 0.866 = 3.464$ inches as the side adjacent.

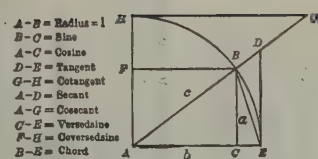
SIMPLE SOLUTIONS OF RIGHT-ANGLE-TRIANGLE PROBLEMS FOR MECHANICS

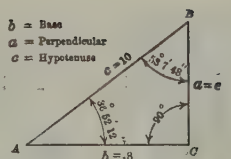
To enable those who have a knowledge of arithmetic only to find easily the different dimensions of the right-angle triangle, this table was prepared by S. A. Hand, Associate Editor, *American Machinist*.

The particular angle chosen for illustration was selected on account of the ease in which the dimensions of the sides could be found by simple arithmetic.

The beginner will of course understand that dimensions of the sides of the triangle can be any other than those given in the illustration but their proportions will remain constant for the same angle.

Complete tables of sines, tangents, secants, etc., will be found on pages 853 to 887.





To Find	Knowing	Rule	Formula	Example
Angle A	Angles B and C	Subtract angle B from angle C.....	C − B = A	$90° - 53° 7' 48'' = 36° 52' 12''$
Angle B	Angles A and C	Subtract angle A from angle C.....	C − A = B	$90° - 36° 52' 12'' = 53° 7' 48''$
Angle C	Angles A and B	Add angle A to angle B.....	A + B = C	$36° 52' 12'' + 53° 7' 48'' = 90°$
Sine A	Sides a and c	Divide side a by side c.....	$\frac{a}{c} = \sin A$	$\frac{6}{10} = 0.60000 = \sin 36° 52' 12''$
	Cosecant A	Divide 1 by cosecant A.....	$\frac{1}{\text{cosec } A} = \sin A$	$\frac{1}{1.66666} = 0.60000 = \sin 36° 52' 12''$
	Tangent A and cosine A	Multiply tangent A by cosine A.....	Tan A × cos A = sin A	$0.75000 \times 0.80000 = 0.60000 = \sin 36° 52' 12''$

	Tangent A and secant A	Divide tangent A by secant A.....	$\frac{\text{Tan A}}{\text{sec A}} = \sin A$	$\frac{0.75000}{1.25000} = 0.60000 = \sin 36^\circ\ 52'\ 12''$
	Cosine A and cotangent A	Divide cosine A by cotangent A.....	$\frac{\text{Cos A}}{\text{cot A}} = \sin A$	$\frac{0.80000}{1.33333} = 0.60000 = \sin 36^\circ\ 52'\ 12''$
	Cosine A	Subtract the square of cosine A from 1 and extract the square root of the remainder..	$\sqrt{1 - \cos A^2} = \sin A$	$\sqrt{0.36} = 0.60000 = \sin 36^\circ\ 52'\ 12''$
Cosine A	Sides b and c	Divide side b by side c.....	$\frac{b}{c} = \cos A$	$\frac{8}{10} = 0.80000 = \cos 36^\circ\ 52'\ 12''$
	Secant A	Divide 1 by secant A.....	$\frac{1}{\text{sec A}} = \cos A$	$\frac{1}{1.25000} = 0.80000 = \cos 36^\circ\ 52'\ 12''$
	Cotangent A and sine A	Multiply cotangent A by sine A.....	$\text{Cot A} \times \sin A = \cos A$	$1.33333 \times 0.60000 = 0.80000 = \cos 36^\circ\ 52'\ 12''$
	Sine A and tangent A	Divide sine A by tangent A.....	$\frac{\text{Sin A}}{\text{tan A}} = \cos A$	$\frac{0.60000}{0.75000} = 0.80000 = \cos 36^\circ\ 52'\ 12''$
	Cotangent A and cosecant A	Divide cotangent A by cosecant A.....	$\frac{\text{Cot A}}{\text{cosec A}} = \cos A$	$\frac{1.33333}{1.66666} = 0.80000 = \cos 36^\circ\ 52'\ 12''$
	Sine A	Subtract the square of sine A from 1 and extract the square root of the remainder.	$\sqrt{1 - \sin A^2} = \cos A$	$\sqrt{0.64} = 0.80000 = \cos 36^\circ\ 52'\ 12''$

To Find	Knowing	Rule	Formula	Example
Tangent A	Sides a and b	Divide side a by side b.	$\frac{a}{b} = \tan A$	$\frac{6}{8} = 0.75000 = \tan 36° 52' 12''$
	Cotangent A	Divide 1 by cotangent A	$\frac{1}{\cot A} = \tan A$	$\frac{1}{1.33333} = 0.75000 = \tan 36° 52' 12''$
	Secant A and sine A	Multiply secant A by sine A.	$\text{Sec } A \times \sin A = \tan A$	$1.25000 \times 0.60000 = 0.75000 = \tan 36° 52' 12''$
	Sine A and cosine A	Divide sine A by cosine A.	$\frac{\text{Sin } A}{\cos A} = \tan A$	$\frac{0.60000}{0.80000} = 0.75000 = \tan 36° 52' 12''$
	Secant A and cosecant A	Divide secant A by cosecant A.	$\frac{\text{Sec } A}{\text{cosec } A} = \tan A$	$\frac{1.25000}{1.66666} = 0.75000 = \tan 36° 52' 12''$
	Secant A	Subtract 1 from the square of secant A and extract the square root of the remainder.	$\sqrt{\text{Sec } A^2 - 1} = \tan A$	$\sqrt{0.5625} = 0.75000 = \tan 36° 52' 12''$
Cotangent A	Sides b and a	Divide side b by side a.	$\frac{b}{a} = \cot A$	$\frac{8}{6} = 1.33333 = \cot 36° 52' 12''$
	Tangent A	Divide 1 by tangent A.	$\frac{1}{\tan A} = \cot A$	$\frac{1}{0.75000} = 1.33333 = \cot 36° 52' 12''$
	Cosecant A and cosine A	Multiply cosecant A by cosine A.	$\text{Cosec } A \times \cos A = \cot A$	$1.66666 \times 0.80000 = 1.33333 = \cot 36° 52' 12''$

	Cosine A and sine A	Divide cosine A by sine A	$\frac{\text{Cos } A}{\text{sin } A} = \text{cot } A$	$\frac{0.80000}{0.60000} = 1.33333 = \text{cot } 36^\circ\ 52'\ 12''$
	Cosecant A and secant A	Divide cosecant A by secant A	$\frac{\text{Cosec } A}{\text{sec } A} = \text{cot } A$	$\frac{1.66666}{1.25000} = 1.33333 = \text{cot } 36^\circ\ 52'\ 12''$
	Cosecant A	Subtract 1 from the square of cosecant A and extract the square root of the remainder	$\sqrt{\text{Cosec } A^2 - 1} = \text{cot } A$	$\sqrt{1.77777} = 1.33333 = \text{cot } 36^\circ\ 52'\ 12''$
Secant A	Sides c and b	Divide side c by side b	$\frac{c}{b} = \text{sec } A$	$\frac{10}{8} = 1.25000 = \text{sec } 36^\circ\ 52'\ 12''$
	Cosine A	Divide 1 by cosine A	$\frac{1}{\text{cos } A} = \text{sec } A$	$\frac{1}{0.80000} = 1.25000 = \text{sec } 36^\circ\ 52'\ 12''$
	Cosecant A and tangent A	Multiply cosecant A by tangent A	$\text{Cosecant } A \times \tan A = \text{sec } A$	$1.66666 \times 0.75000 = 1.25000 = \text{sec } 36^\circ\ 52'\ 12''$
	Tangent A and sine A	Divide tangent A by sine A	$\frac{\text{Tan } A}{\text{sin } A} = \text{sec } A$	$\frac{0.75000}{0.60000} = 1.25000 = \text{sec } 36^\circ\ 52'\ 12''$
	Cosecant A and cotangent A	Divide cosecant A by cotangent A	$\frac{\text{Cosec } A}{\text{cot } A} = \text{sec } A$	$\frac{1.66666}{1.33333} = 1.25000 = \text{sec } 36^\circ\ 52'\ 12''$
	Tangent A	Add 1 to the square of tangent A and extract the square root of the sum	$\sqrt{\text{Tan } A^2 + 1} = \text{sec } A$	$\sqrt{1.5625} = 1.25000 = \text{sec } 36^\circ\ 52'\ 12''$

To Find	Knowing	Rule	Formula	Example
Cosecant A	Sides c and a	Divide side c by side a	$\frac{c}{a}$ = cosec A	$\frac{10}{6}$ = 1.66666 = cosec 36° 52′ 12″
	Sine A	Divide 1 by sine A	$\frac{1}{0.60000}$ = cosec A	$\frac{1}{0.60000}$ = 1.66666 = cosec 36° 52′ 12″
	Secant A and cotangent A	Multiply secant A by cotangent A	Sec A × cot A = cosec A	1.25000 × 1.33333 = 1.66666 = cosec 36° 52′ 12″
	Secant A and tangent A	Divide secant A by tangent A	$\frac{\text{Sec A}}{\tan A}$ = cosec A	$\frac{1.25000}{0.75000}$ = 1.66666 = cosec 36° 52′ 12″
	Cotangent A and cosine A	Divide cotangent A by cosine A	$\frac{\text{Cot A}}{\cos A}$ = cosec A	$\frac{1.33333}{0.80000}$ = 1.66666 = cosec 36° 52′ 12″
	Cotangent A	Add 1 to the square of cotangent A and extract the square root of the sum	$\sqrt{\text{Cot A}^2 + 1}$ = cosec A	$\sqrt{2.77777}$ = 1.66666 = cosec 36° 52′ 12″
Versed sine A	Sides c and b	Subtract side b from side c and divide the remainder by side c	$\frac{c - b}{c}$ = versin A	$\frac{2}{10}$ = 0.20000 = versin 36° 52′ 12″
	Cosine A	Subtract cosine A from 1	1 − cos A = versin A	1 − 0.80000 = 0.20000 = versin 36° 52′ 12″
Coversed sine A	Sides c and a	Subtract side a from side c and divide the remainder by side c	$\frac{c - a}{c}$ = covers A	$\frac{4}{10}$ = 0.40000 = covers 36° 52′ 12″
	Sine A	Subtract sin A from 1	1 − sin A	1 − 0.60000 = 0.40000 = covers 36° 52′ 12″

Chord A	Sine ½ A	Multiply the sine of half the angle A by 2 and by the radius or side c.	$2c \sin \frac{A}{2}$ = chord A	Sin 18° 26′ 6″ = 0.31623 0.31623 × 2 × 10 = 6.3246 = chord 36° 52′ 12″
Side a	Sides c and b	Subtract the square of side b from the square of side c and extract the square root of the remainder.	$\sqrt{c^2 - b^2}$ = side a	$\sqrt{36} = 6$ = side a
	Side c and sine A	Multiply side c by sine A.	c × sin A = side a	10 × 0.60000 = 6 = side a
	Side b and tangent A	Multiply side b by tangent A.	b × tan A = side a	8 × 0.75000 = 6 = side a
	Side b and cotangent A	Divide side b by cotangent A.	$\frac{b}{\cot A}$ = side a	$\frac{8}{0.13333} = 6$ = side a
	Side c and cosecant A	Divide side c by cosecant A.	$\frac{c}{\operatorname{cosec} A}$ = side A	$\frac{10}{1.66666} = 6$ = side a
Side b	Sides c and a	Subtract the square of side a from the square c and extract the square root of the remainder.	$\sqrt{c^2 - a^2}$ = side b	$\sqrt{64} = 8$ = side b
	Side c and cosine A	Multiply side c by cosine A.	c × cos A = side b	10 × 0.80000 = 8 = side b
	Side a and cotangent A	Multiply side a by cotangent A.	a × cot A = side b	6 × 1.33333 = 8 = side b
	Side a and tangent A	Divide side a by tangent A.	$\frac{a}{\tan A}$ = side b	$\frac{6}{0.7500} = 8$ = side b
	Side c and secant A	Divide side c by secant A.	$\frac{c}{\sec A}$ = side b	$\frac{10}{1.25000} = 8$ = side b

To Find	Knowing	Rule	Formula	Example
Side c	Sides a and b	Add the square of side a to the square of side b and extract the square root of the sum	$\sqrt{a^2 + b^2} = \text{side c}$	$\sqrt{6^2 + 8^2} = \sqrt{36 + 64} = \sqrt{100} = 10 = \text{side c}$
	Side b and secant A	Multiply side b by secant A	$b \times \sec A = \text{side c}$	$8 \times 1.25000 = 10 = \text{side c}$
	Side a and cosecant A	Multiply side a by cosecant A	$a \times \operatorname{cosec} A = \text{side c}$	$6 \times 1.66666 = 10 = \text{side c}$
	Side a and sine A	Divide side a by sine A	$\frac{a}{\sin A} = \text{side c}$	$\frac{6}{0.60000} = 10 = \text{side c}$
	Side b and cosine A	Divide side b by cosine A	$\frac{b}{\cos A} = \text{side c}$	$\frac{8}{0.80000} = 10 = \text{side c}$
	Sides c and b and versed sine A	Subtract side b from side c and divide the remainder by versed sine A	$\frac{c - b}{\operatorname{vers} A} = \text{side c}$	$\frac{2}{0.20000} = 10 = \text{side c}$
	Sides c and a and coversed sine A	Subtract side a from side c and divide the remainder by coversed sine A	$\frac{c - a}{\operatorname{covers} A} = \text{side c}$	$\frac{4}{0.40000} = 10 = \text{side c}$

LAYING OUT REGULAR POLYGONS

THE cut-and-try method is to draw a circle and space it off, but it saves time to know what spacing to use or how large a circle to draw to get a figure of the right size. Suppose we wish to lay out any regular figure, such as pentagon or five-sided figure, having sides 1½ inches long.

TABLE OF REGULAR POLYGONS

Number of Sides	Name of Figure	Diameter of Circle that will just enclose when side is 1	Diameter of circle that will just go inside when side is 1	Length of side where diameter of enclosure circle equals 1	Length of side where inside circle equals 1	Angle formed by lines drawn from center to corners	Angle formed by outer sides of figures	To find Area of Figure multiply side by itself and by number in this column
3	Triangle ..	1.1546	.5774	.866	1.732	120°	60°	.4330
4	Square	1.4142	1.	.7071	1.	90	90	1.
5	Pentagon ..	1.7012	1.3764	.5878	.7265	72	108	1.7204
6	Hexagon ..	2.	1.732	.5	.5774	60	120	2.5980
7	Heptagon .	2.3048	2.0766	.4338	.4815	51°-26′	128 4/7	3.6339
8	Octagon...	2.6132	2.4142	.3827	.4142	45	135	4.8284
9	Nonagon ..	2.9238	2.7474	.342	.3639	40	140	6.1818
10	Decagon ..	3.236	3.0776	.309	.3247	36	144	7.6942
11	Undecagon	3.5494	3.4056	.2817	.2936	32°-43	147 3/11	9.3656
12	Dodecagon	3.8638	3.732	.2588	.2679	30	150	11.1961

Using the Table

Looking in the third column we find "Diameter of circle that will just enclose it," and opposite pentagon we find 1.7012 as the circle that will just enclose a pentagon having a side equal to 1. This may be 1 inch or 1 anything else, so as we are dealing in inches we call it inches. As the side of the pentagon is to be 1½ inches we multiply 1.7012 by 1½ and get 2.5518 as the diameter of circle to draw, and take half of this or the radius 1.2759 in the compass to draw the circle. Then with 1½ inches in the dividers we space round circle, and if the work has been carefully done it will just divide it into five equal parts. Connect these points by straight lines, and you have a pentagon with sides 1½ inches long.

If the pentagon is to go inside a circle of given diameter, say 2 inches, look under column 5 which gives "Length of side when diameter of enclosing circle equals 1," and find 0.5878. Multiply by 2 as this is for a 2-inch circle, and the side will be $2 \times 0.5878 = 1.1756$. Take this distance in the dividers and step around the 2-inch circle.

Assume that it is necessary to have a triangular end on a round shaft, how large must the shaft be to give a triangle 1.5 inches on a side?

Look in the table under column 3, and opposite triangle fin 1.1546, meaning that where the side of a triangle is 1, the diamete of a circle that will just enclose it is 1.1546. As the side is 1.5, w have $1.5 \times 1.1546 = 1.7318$, the diameter of the shaft required If the corners need not be sharp probably a shaft 1.625 woul be ample.

Reversing this to find the size of a bearing that can be turned o a triangular bar of this size, look in column 4, which gives th largest circle that will go inside a triangle with a side equal to 1 This gives 0.5774. Multiply this by $1.5 = 0.8661$.

A square taper reamer is to be used which must ream 1 inch a the small end and 1.5 at the back, what size must this be across th flats at both places?

Under column 5 find 0.7071 as the length of the side of a squar when the diameter of the enclosing circle is 1, so this will be the sid of the small end of the reamer and $1.5 \times 0.7071 = 1.0606$ is the sid of the reamer at the large end.

FINDING THE DIAMETER WITHOUT THE CENTER

It sometimes happens in measuring up a machine that we nee to know the radius of curves when the center is not accessible Three such cases are shown in Figs. 9, 10, and 11, the first two bein

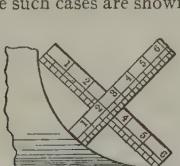


FIG. 9

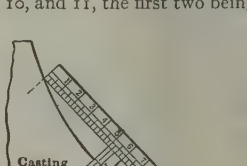


FIG. 10

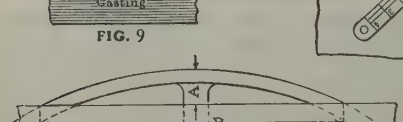


FIG. 11

a machine and the last a broken pulley. In Fig. 9 the rule is shor enough to go in the curve while in Fig. 10 it has one end touchin and the other across the sides. It makes no difference which i used so long as the distances are measured correctly, the short dis tance or *versed sine* being taken at the exact center of the chor and at right angles to it. It is easier figuring when the chord or th height are even inches, so in measuring slip the rule until one or th other comes even; sometimes it is better to make the height com

1 inch and let the chord go as it will, while at others the reverse may be true. The rule for finding the diameter is: Square half the chord, add to this the square of the height, and divide the whole thing by the height.

If the chord is 6 inches as in Fig. 9, and the height $1\frac{1}{2}$ inches we have

$$\frac{\frac{1}{2}\text{chord}^2 + \text{height}^2}{\text{height}} = \frac{3^2 + 1\frac{1}{2}^2}{1\frac{1}{2}} = \frac{9 + 2\frac{1}{4}}{1\frac{1}{2}} = \frac{11\frac{1}{4}}{1\frac{1}{2}} = 7\frac{1}{2} \text{ inches.}$$

Or as in Fig. 10, call the chord 10 inches and the height 1 inch, then the figures are

$$\frac{5^2 + 1^2}{1} = \frac{25 + 1}{1} = 26 \text{ inches.}$$

In Fig. 11 we have a piece of a broken pulley, and find the chord B to be 24 inches, and the height A to be 2 inches. This becomes $\frac{12^2 + 2^2}{2} = \frac{144 + 4}{2} = \frac{148}{2} = 74$, so that the diameter of the pulley is 74 inches

PROPERTIES OF REGULAR FIGURES

The Circle

A circle is a continuous curved line having every point at an equal distance from the center.

Its *perimeter* or circumference is always 3.14159265359 times the diameter, although 3.1416 is generally used and $3\frac{1}{7}$ is a very close approximation.

Area equals the diameter squared × 0.7854, or half the diameter squared × 3.1416, or half the diameter × half the circumference.

Diameter or a square having equal area = diameter of circle times 0.891 very nearly.

Triangle

Equilateral triangle is a regular figure having three equal sides and three equal angles of 60 degrees each.

The *side* equals 0.866 times the diameter of enclosing circle.

Distance from one side to opposite point equals the side times 0.866 or diameter of enclosing circle × 0.75 or inside circle × $1\frac{1}{3}$

Diameter of enclosing circle equals the side times 1.1546 or $1\frac{1}{3}$. times distance from side to point or twice inside circle.

Diameter of inside circle equals side times 0.5774 or $\frac{1}{2}$ the enclosing circle.

The *area* equals one side multiplied by itself and by 0.433013.

Diameter of circle having equal area equals side of triangle times 0.73.

The Square

A square is a figure with four equal sides and four equal angles of 90 degrees.

Its *perimeter* or outside surface is four times the length of one side.

Area equals one side multiplied by the other which is the same as multiplying by itself or "squaring."

Diagonal or "long diameter," or "distance across corners," equals the side multiplied by 1.414.

Area of circle that will go inside the square equals one side multiplied by itself times 0.7854 or 0.7854 times the area of the square.

Area of circle that will just enclose the square equals diagonal multiplied by itself times 0.7854 or 1.27 times the area of the square.

Diameter of a circle having an equal area is 1.126 or practically $1\frac{1}{8}$ times the side of the square.

The Hexagon

A hexagon is a regular figure with six equal sides and six equal angles of 120 degrees. It can be drawn inside a circle by spacing around with the radius of the circle.

The *side* equals half the diameter of enclosing circle.

The *long diameter* equals diameter of enclosing circle or twice the length of one side.

The *short diameter* equals the long diameter multiplied by 0.866 or 1.732 times one side.

The *area* equals one side multiplied by itself and by 2.5981.

The *area* of enclosing circle is one side multiplied by itself and by 3.1416.

The *area* of an inside circle is the short diameter multiplied by itself and by 0.7854.

Diameter of circle having equal area is practically 0.9 times long diameter.

The Octagon

An octagon is a regular figure with eight equal sides and eight equal angles of 135 degrees.

The *side* equals the long diameter multiplied by 0.382.

The *side* equals the short diameter multiplied by 0.415.

The *long diameter* equals diameter of enclosing circle or one side multiplied by 2.62.

The *short diameter* equals the long diameter multiplied by 0.93, or one side multiplied by 2.414.

The *area* equals one side multiplied by itself and by 4.8284.

The area of enclosing circle is 1.126 times area of octagon.

The area of inside circle is 0.972 times area of octagon.

The diameter of a circle having equal area is 0.953 times the long diameter of the octagon.

′	0° Tan.	0° Co-tan.	1° Tan.	1° Co-tan.	2° Tan.	2° Co-tan.	3° Tan.	3° Co-tan.	′
0	.00000	Infinite.	.01746	57.2900	.03492	28.6363	.05241	19.0811	60
1	.00029	3437.750	.01775	56.3506	.03521	28.3994	.05270	18.9755	59
2	.00058	1718.870	.01804	55.4415	.03550	28.1664	.05299	18.8711	58
3	.00087	1145.920	.01833	54.5613	.03579	27.9372	.05328	18.7678	57
4	.00116	859.436	.01862	53.7086	.03609	27.7117	.05357	18.6656	56
5	.00145	687.549	.01891	52.8821	.03638	27.4899	.05387	18.5645	55
6	.00175	572.957	.01920	52.0807	.03667	27.2715	.05416	18.4645	54
7	.00204	491.106	.01949	51.3032	.03696	27.0566	.05445	18.3655	53
8	.00233	429.718	.01978	50.5485	.03725	26.8450	.05474	18.2677	52
9	.00262	381.971	.02007	49.8157	.03754	26.6367	.05503	18.1708	51
10	.00291	343.774	.02036	49.1039	.03783	26.4316	.05533	18.0750	50
11	.00320	312.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	49
12	.00349	286.478	.02095	47.7395	.03842	26.0307	.05591	17.8863	48
13	.00378	264.441	.02124	47.0853	.03871	25.8348	.05620	17.7934	47
14	.00407	245.552	.02153	46.4489	.03900	25.6418	.05649	17.7015	46
15	.00436	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	45
16	.00465	214.858	.02211	45.2261	.03958	25.2644	.05708	17.5205	44
17	.00495	202.219	.02240	44.6386	.03987	25.0798	.05737	17.4314	43
18	.00524	190.984	.02269	44.0661	.04016	24.8978	.05766	17.3432	42
19	.00553	180.932	.02298	43.5081	.04046	24.7185	.05795	17.2558	41
20	.00582	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	40
21	.00611	163.700	.02357	42.4335	.04104	24.3675	.05854	17.0837	39
22	.00640	156.259	.02386	41.9158	.04133	24.1957	.05883	16.9990	38
23	.00669	149.465	.02415	41.4106	.04162	24.0263	.05912	16.9150	37
24	.00698	143.237	.02444	40.9174	.04191	23.8593	.05941	16.8319	36
25	.00727	137.507	.02473	40.4358	.04220	23.6945	.05970	16.7496	35
26	.00756	132.219	.02502	39.9655	.04250	23.5321	.05999	16.6681	34
27	.00785	127.321	.02531	39.5059	.04279	23.3718	.06029	16.5874	33
28	.00814	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5075	32
29	.00844	118.540	.02589	38.6177	.04337	23.0577	.06087	16.4283	31
30	.00873	114.589	.02619	38.1885	.04366	22.9038	.06116	16.3499	30
31	.00902	110.892	.02648	37.7686	.04395	22.7519	.06145	16.2722	29
32	.00931	107.426	.02677	37.3579	.04424	22.6020	.06175	16.1952	28
33	.00960	104.171	.02706	36.9560	.04454	22.4541	.06204	16.1190	27
34	.00989	101.107	.02735	36.5627	.04483	22.3081	.06233	16.0435	26
35	.01018	98.2179	.02764	36.1776	.04512	22.1640	.06262	15.9687	25
36	.01047	95.4895	.02793	35.8006	.04541	22.0217	.06291	15.8945	24
37	.01076	92.9085	.02822	35.4313	.04570	21.8813	.06321	15.8211	23
38	.01105	90.4633	.02851	35.0695	.04599	21.7426	.06350	15.7483	22
39	.01135	88.1436	.02881	34.7151	.04628	21.6056	.06379	15.6762	21
40	.01164	85.9398	.02910	34.3678	.04658	21.4704	.06408	15.6048	20
41	.01193	83.8435	.02939	34.0273	.04687	21.3369	.06437	15.5340	19
42	.01222	81.8470	.02968	33.6935	.04716	21.2049	.06467	15.4638	18
43	.01251	79.9434	.02997	33.3662	.04745	21.0747	.06496	15.3943	17
44	.01280	78.1263	.03026	33.0452	.04774	20.9460	.06525	15.3254	16
45	.01309	76.3900	.03055	32.7303	.04803	20.8188	.06554	15.2571	15
46	.01338	74.7292	.03084	32.4213	.04832	20.6932	.06584	15.1893	14
47	.01367	73.1390	.03114	32.1181	.04862	20.5691	.06613	15.1222	13
48	.01396	71.6151	.03143	31.8205	.04891	20.4465	.06642	15.0557	12
49	.01425	70.1533	.03172	31.5284	.04920	20.3253	.06671	14.9898	11
50	.01455	68.7501	.03201	31.2416	.04949	20.2056	.06700	14.9244	10
51	.01484	67.4019	.03230	30.9599	.04978	20.0872	.06730	14.8596	9
52	.01513	66.1055	.03259	30.6833	.05007	19.9702	.06759	14.7954	8
53	.01542	64.8580	.03288	30.4116	.05037	19.8546	.06788	14.7317	7
54	.01571	63.6567	.03317	30.1446	.05066	19.7403	.06817	14.6685	6
55	.01600	62.4992	.03346	29.8823	.05095	19.6273	.06847	14.6059	5
56	.01629	61.3829	.03376	29.6245	.05124	19.5156	.06876	14.5438	4
57	.01658	60.3058	.03405	29.3711	.05153	19.4051	.06905	14.4823	3
58	.01687	59.2659	.03434	29.1220	.05182	19.2959	.06934	14.4212	2
59	.01716	58.2612	.03463	28.8771	.05212	19.1879	.06963	14.3607	1
60	.01746	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	89°		88°		87°		86°		

′	4° Tan.	4° Co-tan.	5° Tan.	5° Co-tan.	6° Tan.	6° Co-tan.	7° Tan.	7° Co-tan.	′
0	.06993	14.3007	.08749	11.4301	.10510	9.51436	.12278	8.14435	60
1	.07022	14.2411	.08778	11.3919	.10540	9.48781	.12308	8.12481	59
2	.07051	14.1821	.08807	11.3540	.10569	9.46141	.12338	8.10536	58
3	.07080	14.1235	.08837	11.3163	.10599	9.43515	.12367	8.08600	57
4	.07110	14.0655	.08866	11.2789	.10628	9.40904	.12397	8.06674	56
5	.07139	14.0079	.08895	11.2417	.10657	9.38307	.12426	8.04756	55
6	.07168	13.9507	.08925	11.2048	.10687	9.35724	.12456	8.02848	54
7	.07197	13.8940	.08954	11.1681	.10716	9.33154	.12485	8.00948	53
8	.07227	13.8378	.08983	11.1316	.10746	9.30599	.12515	7.99058	52
9	.07256	13.7821	.09013	11.0954	.10775	9.28058	.12544	7.97176	51
10	.07285	13.7267	.09042	11.0594	.10805	9.25530	.12574	7.95302	50
11	.07314	13.6719	.09071	11.0237	.10834	9.23016	.12603	7.93438	49
12	.07344	13.6174	.09101	10.9882	.10863	9.20516	.12633	7.91582	48
13	.07373	13.5634	.09130	10.9529	.10893	9.18028	.12662	7.89734	47
14	.07402	13.5098	.09159	10.9178	.10922	9.15554	.12692	7.87895	46
15	.07431	13.4566	.09189	10.8829	.10952	9.13093	.12722	7.86064	45
16	.07461	13.4039	.09218	10.8483	.10981	9.10646	.12751	7.84242	44
17	.07490	13.3515	.09247	10.8139	.11011	9.08211	.12781	7.82428	43
18	.07519	13.2996	.09277	10.7797	.11040	9.05789	.12810	7.80622	42
19	.07548	13.2480	.09306	10.7457	.11070	9.03379	.12840	7.78825	41
20	.07578	13.1969	.09335	10.7119	.11099	9.00983	.12869	7.77035	40
21	.07607	13.1461	.09365	10.6783	.11128	8.98598	.12899	7.75254	39
22	.07636	13.0958	.09394	10.6450	.11158	8.96227	.12929	7.73480	38
23	.07665	13.0458	.09423	10.6118	.11187	8.93867	.12958	7.71715	37
24	.07695	12.9962	.09453	10.5789	.11217	8.91520	.12988	7.69957	36
25	.07724	12.9469	.09482	10.5462	.11246	8.89185	.13017	7.68208	35
26	.07753	12.8981	.09511	10.5136	.11276	8.86862	.13047	7.66466	34
27	.07782	12.8496	.09541	10.4813	.11305	8.84551	.13076	7.64732	33
28	.07812	12.8014	.09570	10.4491	.11335	8.82252	.13106	7.63005	32
29	.07841	12.7536	.09600	10.4172	.11364	8.79964	.13136	7.61287	31
30	.07870	12.7062	.09629	10.3854	.11394	8.77689	.13165	7.59575	30
31	.07899	12.6591	.09658	10.3538	.11423	8.75425	.13195	7.57872	29
32	.07929	12.6124	.09688	10.3224	.11452	8.73172	.13224	7.56176	28
33	.07958	12.5660	.09717	10.2913	.11482	8.70931	.13254	7.54487	27
34	.07987	12.5199	.09746	10.2602	.11511	8.68701	.13284	7.52806	26
35	.08017	12.4742	.09776	10.2294	.11541	8.66482	.13313	7.51132	25
36	.08046	12.4288	.09805	10.1988	.11570	8.64275	.13343	7.49465	24
37	.08075	12.3838	.09834	10.1683	.11600	8.62078	.13372	7.47806	23
38	.08104	12.3390	.09864	10.1381	.11629	8.59893	.13402	7.46154	22
39	.08134	12.2946	.09893	10.1080	.11659	8.57718	.13432	7.44509	21
40	.08163	12.2505	.09923	10.0780	.11688	8.55555	.13461	7.42871	20
41	.08192	12.2067	.09952	10.0483	.11718	8.53402	.13491	7.41240	19
42	.08221	12.1632	.09981	10.0187	.11747	8.51259	.13521	7.39616	18
43	.08251	12.1201	.10011	9.98931	.11777	8.49128	.13550	7.37999	17
44	.08280	12.0772	.10040	9.96007	.11806	8.47007	.13580	7.36389	16
45	.08309	12.0346	.10069	9.93101	.11836	8.44896	.13609	7.34786	15
46	.08339	11.9923	.10099	9.90211	.11865	8.42795	.13639	7.33190	14
47	.08368	11.9504	.10128	9.87338	.11895	8.40705	.13669	7.31600	13
48	.08397	11.9087	.10158	9.84482	.11924	8.38625	.13698	7.30018	12
49	.08427	11.8673	.10187	9.81641	.11954	8.36555	.13728	7.28442	11
50	.08456	11.8262	.10216	9.78817	.11983	8.34496	.13758	7.26873	10
51	.08485	11.7853	.10246	9.76009	.12013	8.32446	.13787	7.25310	9
52	.08514	11.7448	.10275	9.73217	.12042	8.30406	.13817	7.23754	8
53	.08544	11.7045	.10305	9.70441	.12072	8.28376	.13846	7.22204	7
54	.08573	11.6645	.10334	9.67680	.12101	8.26355	.13876	7.20661	6
55	.08602	11.6248	.10303	9.64935	.12131	8.24345	.13906	7.19125	5
56	.08632	11.5853	.10393	9.62205	.12160	8.22344	.13935	7.17594	4
57	.08661	11.5461	.10422	9.59490	.12190	8.20352	.13965	7.16071	3
58	.08690	11.5072	.10452	9.56791	.12219	8.18370	.13995	7.14553	2
59	.08720	11.4685	.10481	9.54106	.12249	8.16398	.14024	7.13042	1
60	.08749	11.4301	.10510	9.51436	.12278	8.14435	.14054	7.11537	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	85°		84°		83°		82°		

′	8° Tan.	8° Co-tan.	9° Tan.	9° Co-tan.	10° Tan.	10° Co-tan.	11° Tan.	11° Co-tan.	′
0	.14054	7.11537	.15838	6.31375	.17633	5.67128	.19438	5.14455	60
1	.14084	7.10038	.15868	6.30189	.17663	5.66165	.19468	5.13658	59
2	.14113	7.08546	.15898	6.29007	.17693	5.65205	.19498	5.12862	58
3	.14143	7.07059	.15928	6.27829	.17723	5.64248	.19529	5.12069	57
4	.14173	7.05579	.15958	6.26655	.17753	5.63295	.19559	5.11279	56
5	.14202	7.04105	.15988	6.25486	.17783	5.62344	.19589	5.10490	55
6	.14232	7.02637	.16017	6.24321	.17813	5.61397	.19619	5.09704	54
7	.14262	7.01174	.16047	6.23160	.17843	5.60452	.19649	5.08921	53
8	.14291	6.99718	.16077	6.22003	.17873	5.59511	.19680	5.08139	52
9	.14321	6.98268	.16107	6.20851	.17903	5.58573	.19710	5.07360	51
10	.14351	6.96823	.16137	6.19703	.17933	5.57638	.19740	5.06584	50
11	.14381	6.95385	.16167	6.18559	.17963	5.56706	.19770	5.05809	49
12	.14410	6.93952	.16196	6.17419	.17993	5.55777	.19801	5.05037	48
13	.14440	6.92525	.16226	6.16283	.18023	5.54851	.19831	5.04267	47
14	.14470	6.91104	.16256	6.15151	.18053	5.53927	.19861	5.03499	46
15	.14499	6.89688	.16286	6.14023	.18083	5.53007	.19891	5.02734	45
16	.14529	6.88278	.16316	6.12899	.18113	5.52090	.19921	5.01971	44
17	.14559	6.86874	.16346	6.11779	.18143	5.51176	.19952	5.01210	43
18	.14588	6.85475	.16376	6.10664	.18173	5.50264	.19982	5.00451	42
19	.14618	6.84082	.16405	6.09552	.18203	5.49356	.20012	4.99695	41
20	.14648	6.82694	.16435	6.08444	.18233	5.48451	.20042	4.98940	40
21	.14678	6.81312	.16465	6.07340	.18263	5.47548	.20073	4.98188	39
22	.14707	6.79936	.16495	6.06240	.18293	5.46648	.20103	4.97438	38
23	.14737	6.78564	.16525	6.05143	.18323	5.45751	.20133	4.96690	37
24	.14767	6.77199	.16555	6.04051	.18353	5.44857	.20164	4.95945	36
25	.14796	6.75838	.16585	6.02962	.18383	5.43966	.20194	4.95201	35
26	.14826	6.74483	.16615	6.01878	.18414	5.43077	.20224	4.94460	34
27	.14856	6.73133	.16645	6.00797	.18444	5.42192	.20254	4.93721	33
28	.14886	6.71789	.16674	5.99720	.18474	5.41309	.20285	4.92984	32
29	.14915	6.70450	.16704	5.98646	.18504	5.40429	.20315	4.92249	31
30	.14945	6.69116	.16734	5.97576	.18534	5.39552	.20345	4.91516	30
31	.14975	6.67787	.16764	5.96510	.18564	5.38677	.20376	4.90785	29
32	.15005	6.66463	.16794	5.95448	.18594	5.37805	.20406	4.90056	28
33	.15034	6.65144	.16824	5.94390	.18624	5.36936	.20436	4.89330	27
34	.15064	6.63831	.16854	5.93335	.18654	5.36070	.20466	4.88605	26
35	.15094	6.62523	.16884	5.92283	.18684	5.35206	.20497	4.87882	25
36	.15124	6.61219	.16914	5.91235	.18714	5.34345	.20527	4.87162	24
37	.15153	6.59921	.16944	5.90191	.18745	5.33487	.20557	4.86444	23
38	.15183	6.58627	.16974	5.89151	.18775	5.32631	.20588	4.85727	22
39	.15213	6.57339	.17004	5.88114	.18805	5.31778	.20618	4.85013	21
40	.15243	6.56055	.17033	5.87080	.18835	5.30928	.20648	4.84300	20
41	.15272	6.54777	.17063	5.86051	.18865	5.30080	.20679	4.83590	19
42	.15302	6.53503	.17093	5.85024	.18895	5.29235	.20709	4.82882	18
43	.15332	6.52234	.17123	5.84001	.18925	5.28393	.20739	4.82175	17
44	.15362	6.50970	.17153	5.82982	.18955	5.27553	.20770	4.81471	16
45	.15391	6.49710	.17183	5.81966	.18986	5.26715	.20800	4.80769	15
46	.15421	6.48456	.17213	5.80953	.19016	5.25880	.20830	4.80068	14
47	.15451	6.47206	.17243	5.79944	.19046	5.25048	.20861	4.79370	13
48	.15481	6.45961	.17273	5.78938	.19076	5.24218	.20891	4.78673	12
49	.15511	6.44720	.17303	5.77936	.19106	5.23391	.20921	4.77978	11
50	.15540	6.43484	.17333	5.76937	.19136	5.22566	.20952	4.77286	10
51	.15570	6.42253	.17363	5.75941	.19166	5.21744	.20982	4.76595	9
52	.15600	6.41026	.17393	5.74949	.19197	5.20925	.21013	4.75906	8
53	.15630	6.39804	.17423	5.73960	.19227	5.20107	.21043	4.75219	7
54	.15660	6.38587	.17453	5.72974	.19257	5.19293	.21073	4.74534	6
55	.15689	6.37374	.17483	5.71992	.19287	5.18480	.21104	4.73851	5
56	.15719	6.36165	.17513	5.71013	.19317	5.17671	.21134	4.73170	4
57	.15749	6.34961	.17543	5.70037	.19347	5.16863	.21164	4.72490	3
58	.15779	6.33761	.17573	5.69064	.19378	5.16058	.21195	4.71813	2
59	.15809	6.32566	.17603	5.68094	.19408	5.15256	.21225	4.71137	1
60	.15838	6.31375	.17633	5.67128	.19438	5.14455	.21256	4.70463	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	81°		80°		79°		78°		

′	12° Tan.	12° Co-tan.	13° Tan.	13° Co-tan.	14° Tan.	14° Co-tan.	15° Tan.	15° Co-tan	′
0	.21256	4.70463	.23087	4.33148	.24933	4.01078	.26795	3.73205	60
1	.21286	4.69791	.23117	4.32573	.24964	4.00582	.26826	3.72771	59
2	.21316	4.69121	.23148	4.32001	.24995	4.00086	.26857	3.72338	58
3	.21347	4.68452	.23179	4.31430	.25026	3.99592	.26888	3.71907	57
4	.21377	4.67786	.23209	4.30860	.25056	3.99099	.26920	3.71476	56
5	.21408	4.67121	.23240	4.30291	.25087	3.98607	.26951	3.71046	55
6	.21438	4.66458	.23271	4.29724	.25118	3.98117	.26982	3.70616	54
7	.21469	4.65797	.23301	4.29159	.25149	3.97627	.27013	3.70188	53
8	.21499	4.65138	.23332	4.28595	.25180	3.97139	.27044	3.69761	52
9	.21529	4.64480	.23363	4.28032	.25211	3.96651	.27076	3.69335	51
10	.21560	4.63825	.23393	4.27471	.25242	3.96165	.27107	3.68909	50
11	.21590	4.63171	.23424	4.26911	.25273	3.95680	.27138	3.68485	49
12	.21621	4.62518	.23455	4.26352	.25304	3.95196	.27169	3.68061	48
13	.21651	4.61868	.23485	4.25795	.25335	3.94713	.27201	3.67638	47
14	.21682	4.61219	.23516	4.25239	.25366	3.94232	.27232	3.67217	46
15	.21712	4.60572	.23547	4.24685	.25397	3.93751	.27263	3.66796	45
16	.21743	4.59927	.23578	4.24132	.25428	3.93271	.27294	3.66376	44
17	.21773	4.59283	.23608	4.23580	.25459	3.92793	.27326	3.65957	43
18	.21804	4.58641	.23639	4.23030	.25490	3.92316	.27357	3.65538	42
19	.21834	4.58001	.23670	4.22481	.25521	3.91839	.27388	3.65121	41
20	.21864	4.57363	.23700	4.21933	.25552	3.91364	.27419	3.64705	40
21	.21895	4.56726	.23731	4.21387	.25583	3.90890	.27451	3.64289	39
22	.21925	4.56091	.23762	4.20842	.25614	3.90417	.27482	3.63874	38
23	.21956	4.55458	.23793	4.20298	.25645	3.89945	.27513	3.63461	37
24	.21986	4.54826	.23823	4.19756	.25676	3.89474	.27545	3.63048	36
25	.22017	4.54196	.23854	4.19215	.25707	3.89004	.27576	3.62636	35
26	.22047	4.53568	.23885	4.18675	.25738	3.88536	.27607	3.62224	34
27	.22078	4.52941	.23916	4.18137	.25769	3.88068	.27638	3.61814	33
28	.22108	4.52316	.23946	4.17600	.25800	3.87601	.27670	3.61405	32
29	.22139	4.51693	.23977	4.17064	.25831	3.87136	.27701	3.60996	31
30	.22169	4.51071	.24008	4.16530	.25862	3.86671	.27732	3.60588	30
31	.22200	4.50451	.24039	4.15997	.25893	3.86208	.27764	3.60181	29
32	.22231	4.49832	.24069	4.15465	.25924	3.85745	.27795	3.59775	28
33	.22261	4.49215	.24100	4.14934	.25955	3.85284	.27826	3.59370	27
34	.22292	4.48600	.24131	4.14405	.25986	3.84824	.27858	3.58966	26
35	.22322	4.47986	.24162	4.13877	.26017	3.84364	.27889	3.58562	25
36	.22353	4.47374	.24193	4.13350	.26048	3.83906	.27920	3.58160	24
37	.22383	4.46764	.24223	4.12825	.26079	3.83449	.27952	3.57758	23
38	.22414	4.46155	.24254	4.12301	.26110	3.82992	.27983	3.57357	22
39	.22444	4.45548	.24285	4.11778	.26141	3.82537	.28015	3.56957	21
40	.22475	4.44942	.24316	4.11256	.26172	3.82083	.28046	3.56557	20
41	.22505	4.44338	.24347	4.10736	.26203	3.81630	.28077	3.56159	19
42	.22536	4.43735	.24377	4.10216	.26235	3.81177	.28109	3.55761	18
43	.22567	4.43134	.24408	4.09699	.26266	3.80726	.28140	3.55364	17
44	.22597	4.42534	.24439	4.09182	.26297	3.80276	.28172	3.54968	16
45	.22628	4.41936	.24470	4.08666	.26328	3.79827	.28203	3.54573	15
46	.22658	4.41340	.24501	4.08152	.26359	3.79378	.28234	3.54179	14
47	.22689	4.40745	.24532	4.07639	.26390	3.78931	.28266	3.53785	13
48	.22719	4.40152	.24562	4.07127	.26421	3.78485	.28297	3.53393	12
49	.22750	4.39560	.24593	4.06616	.26452	3.78040	.28329	3.53001	11
50	.22781	4.38969	.24624	4.06107	.26483	3.77595	.28360	3.52609	10
51	.22811	4.38381	.24655	4.05599	.26515	3.77152	.28391	3.52219	9
52	.22842	4.37793	.24686	4.05092	.26546	3.76709	.28423	3.51829	8
53	.22872	4.37207	.24717	4.04586	.26577	3.76268	.28454	3.51441	7
54	.22903	4.36623	.24747	4.04081	.26608	3.75828	.28486	3.51053	6
55	.22934	4.36040	.24778	4.03578	.26639	3.75388	.28517	3.50666	5
56	.22964	4.35459	.24809	4.03075	.26670	3.74950	.28549	3.50279	4
57	.22995	4.34879	.24840	4.02574	.26701	3.74512	.28580	3.49894	3
58	.23026	4.34300	.24871	4.02074	.26733	3.74075	.28612	3.49509	2
59	.23056	4.33723	.24902	4.01576	.26764	3.73640	.28643	3.49125	1
60	.23087	4.33148	.24933	4.01078	.26795	3.73205	.28675	3.48741	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	77°		76°		75°		74°		

′	16° Tan.	16° Co-tan.	17° Tan.	17° Co-tan.	18° Tan.	18° Co-tan.	19° Tan.	19° Co-tan.	′
0	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	60
1	.28706	3.48359	.30605	3.26745	.32524	3.07464	.34465	2.90147	59
2	.28738	3.47977	.30637	3.26406	.32556	3.07160	.34498	2.89873	58
3	.28769	3.47596	.30669	3.26067	.32588	3.06857	.34530	2.89600	57
4	.28800	3.47216	.30700	3.25729	.32621	3.06554	.34563	2.89327	56
5	.28832	3.46837	.30732	3.25392	.32653	3.06252	.34596	2.89055	55
6	.28864	3.46458	.30764	3.25055	.32685	3.05950	.34628	2.88783	54
7	.28895	3.46080	.30796	3.24719	.32717	3.05649	.34661	2.88511	53
8	.28927	3.45703	.30828	3.24383	.32749	3.05349	.34693	2.88240	52
9	.28958	3.45327	.30860	3.24049	.32782	3.05049	.34726	2.87970	51
10	.28990	3.44951	.30891	3.23714	.32814	3.04749	.34758	2.87700	50
11	.29021	3.44576	.30923	3.23381	.32846	3.04450	.34791	2.87430	49
12	.29053	3.44202	.30955	3.23048	.32878	3.04152	.34824	2.87161	48
13	.29084	3.43829	.30987	3.22715	.32911	3.03854	.34856	2.86892	47
14	.29116	3.43456	.31019	3.22384	.32943	3.03556	.34889	2.86624	46
15	.29147	3.43084	.31051	3.22053	.32975	3.03260	.34922	2.86356	45
16	.29179	3.42713	.31083	3.21722	.33007	3.02963	.34954	2.86089	44
17	.29210	3.42343	.31115	3.21392	.33040	3.02667	.34987	2.85822	43
18	.29242	3.41973	.31147	3.21063	.33072	3.02372	.35019	2.85555	42
19	.29274	3.41604	.31178	3.20734	.33104	3.02077	.35052	2.85289	41
20	.29305	3.41236	.31210	3.20406	.33136	3.01783	.35085	2.85023	40
21	.29337	3.40869	.31242	3.20079	.33169	3.01489	.35117	2.84758	39
22	.29368	3.40502	.31274	3.19752	.33201	3.01196	.35150	2.84494	38
23	.29400	3.40136	.31306	3.19426	.33233	3.00903	.35183	2.84229	37
24	.29432	3.39771	.31338	3.19100	.33266	3.00611	.35216	2.83965	36
25	.29463	3.39406	.31370	3.18775	.33298	3.00319	.35248	2.83702	35
26	.29495	3.39042	.31402	3.18451	.33330	3.00028	.35281	2.83439	34
27	.29526	3.38679	.31434	3.18127	.33363	2.99738	.35314	2.83176	33
28	.29558	3.38317	.31466	3.17804	.33395	2.99447	.35346	2.82914	32
29	.29590	3.37955	.31498	3.17481	.33427	2.99158	.35379	2.82653	31
30	.29621	3.37594	.31530	3.17159	.33460	2.98868	.35412	2.82391	30
31	.29653	3.37234	.31562	3.16838	.33492	2.98580	.35445	2.82130	29
32	.29685	3.36875	.31594	3.16517	.33524	2.98292	.35477	2.81870	28
33	.29716	3.36516	.31626	3.16197	.33557	2.98004	.35510	2.81610	27
34	.29748	3.36158	.31658	3.15877	.33589	2.97717	.35543	2.81350	26
35	.29780	3.35800	.31690	3.15558	.33621	2.97430	.35576	2.81091	25
36	.29811	3.35443	.31722	3.15240	.33654	2.97144	.35608	2.80833	24
37	.29843	3.35087	.31754	3.14922	.33686	2.96858	.35641	2.80574	23
38	.29875	3.34732	.31786	3.14605	.33718	2.96573	.35674	2.80316	22
39	.29906	3.34377	.31818	3.14288	.33751	2.96288	.35707	2.80059	21
40	.29938	3.34023	.31850	3.13972	.33783	2.96004	.35740	2.79802	20
41	.29970	3.33670	.31882	3.13656	.33816	2.95721	.35772	2.79545	19
42	.30001	3.33317	.31914	3.13341	.33848	2.95437	.35805	2.79289	18
43	.30033	3.32965	.31946	3.13027	.33881	2.95155	.35838	2.79033	17
44	.30065	3.32614	.31978	3.12713	.33913	2.94872	.35871	2.78778	16
45	.30097	3.32264	.32010	3.12400	.33945	2.94590	.35904	2.78523	15
46	.30128	3.31914	.32042	3.12087	.33978	2.94309	.35937	2.78269	14
47	.30160	3.31565	.32074	3.11775	.34010	2.94028	.35969	2.78014	13
48	.30192	3.31216	.32106	3.11464	.34043	2.93748	.36002	2.77761	12
49	.30224	3.30868	.32139	3.11153	.34075	2.93468	.36035	2.77507	11
50	.30255	3.30521	.32171	3.10842	.34108	2.93189	.36068	2.77254	10
51	.30287	3.30174	.32203	3.10532	.34140	2.92910	.36101	2.77002	9
52	.30319	3.29829	.32235	3.10223	.34173	2.92632	.36134	2.76750	8
53	.30351	3.29483	.32267	3.09914	.34205	2.92354	.36167	2.76498	7
54	.30382	3.29139	.32299	3.09606	.34238	2.92076	.36199	2.76247	6
55	.30414	3.28795	.32331	3.09298	.34270	2.91799	.36232	2.75996	5
56	.30446	3.28452	.32363	3.08991	.34303	2.91523	.36265	2.75746	4
57	.30478	3.28109	.32396	3.08685	.34335	2.91246	.36298	2.75496	3
58	.30509	3.27767	.32428	3.08379	.34368	2.90971	.36331	2.75246	2
59	.30541	3.27426	.32460	3.08073	.34400	2.90696	.36364	2.74997	1
60	.30573	3.27085	.32492	3.07768	.34433	2.90421	.36397	2.74748	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	73°		72°		71°		70°		

′	20° Tan.	20° Co-tan.	21° Tan.	21° Co-tan.	22° Tan.	22° Co-tan.	23° Tan.	23° Co-tan.	′
0	.36397	2.74748	.38386	2.60509	.40403	2.47509	.42447	2.35585	60
1	.36430	2.74499	.38420	2.60283	.40436	2.47302	.42482	2.35395	59
2	.36463	2.74251	.38453	2.60057	.40470	2.47095	.42516	2.35205	58
3	.36496	2.74004	.38487	2.59831	.40504	2.46888	.42551	2.35015	57
4	.36529	2.73756	.38520	2.59606	.40538	2.46682	.42585	2.34825	56
5	.36562	2.73509	.38553	2.59381	.40572	2.46476	.42619	2.34636	55
6	.36595	2.73263	.38587	2.59156	.40606	2.46270	.42654	2.34447	54
7	.36628	2.73017	.38620	2.58932	.40640	2.46065	.42688	2.34258	53
8	.36661	2.72771	.38654	2.58708	.40674	2.45860	.42722	2.34069	52
9	.36694	2.72526	.38687	2.58484	.40707	2.45655	.42757	2.33881	51
10	.36727	2.72281	.38721	2.58261	.40741	2.45451	.42791	2.33693	50
11	.36760	2.72036	.38754	2.58038	.40775	2.45246	.42826	2.33505	49
12	.36793	2.71792	.38787	2.57815	.40809	2.45043	.42860	2.33317	48
13	.36826	2.71548	.38821	2.57593	.40843	2.44839	.42894	2.33130	47
14	.36859	2.71305	.38854	2.57371	.40877	2.44636	.42929	2.32943	46
15	.36892	2.71062	.38888	2.57150	.40911	2.44433	.42963	2.32756	45
16	.36925	2.70819	.38921	2.56928	.40945	2.44230	.42998	2.32570	44
17	.36958	2.70577	.38955	2.56707	.40979	2.44027	.43032	2.32383	43
18	.36991	2.70335	.38988	2.56487	.41013	2.43825	.43067	2.32197	42
19	.37024	2.70094	.39022	2.56266	.41047	2.43623	.43101	2.32012	41
20	.37057	2.69853	.39055	2.56046	.41081	2.43422	.43136	2.31826	40
21	.37090	2.69612	.39089	2.55827	.41115	2.43220	.43170	2.31641	39
22	.37124	2.69371	.39122	2.55608	.41149	2.43019	.43205	2.31456	38
23	.37157	2.69131	.39156	2.55389	.41183	2.42819	.43239	2.31271	37
24	.37190	2.68892	.39190	2.55170	.41217	2.42618	.43274	2.31086	36
25	.37223	2.68653	.39223	2.54952	.41251	2.42418	.43308	2.30902	35
26	.37256	2.68414	.39257	2.54734	.41285	2.42218	.43343	2.30718	34
27	.37289	2.68175	.39290	2.54516	.41319	2.42019	.43378	2.30534	33
28	.37322	2.67937	.39324	2.54299	.41353	2.41819	.43412	2.30351	32
29	.37355	2.67700	.39357	2.54082	.41387	2.41620	.43447	2.30167	31
30	.37388	2.67462	.39391	2.53865	.41421	2.41421	.43481	2.29984	30
31	.37422	2.67225	.39425	2.53648	.41455	2.41223	.43516	2.29801	29
32	.37455	2.66989	.39458	2.53432	.41490	2.41025	.43550	2.29619	28
33	.37488	2.66752	.39492	2.53217	.41524	2.40827	.43585	2.29437	27
34	.37521	2.66516	.39526	2.53001	.41558	2.40629	.43620	2.29254	26
35	.37554	2.66281	.39559	2.52786	.41592	2.40432	.43654	2.29073	25
36	.37588	2.66046	.39593	2.52571	.41626	2.40235	.43689	2.28891	24
37	.37621	2.65811	.39626	2.52357	.41660	2.40038	.43724	2.28710	23
38	.37654	2.65576	.39660	2.52142	.41694	2.39841	.43758	2.28528	22
39	.37687	2.65342	.39694	2.51929	.41728	2.39645	.43793	2.28348	21
40	.37720	2.65109	.39727	2.51715	.41763	2.39449	.43828	2.28167	20
41	.37754	2.64875	.39761	2.51502	.41797	2.39253	.43862	2.27987	19
42	.37787	2.64642	.39795	2.51289	.41831	2.39058	.43897	2.27806	18
43	.37820	2.64410	.39829	2.51076	.41865	2.38862	.43932	2.27626	17
44	.37853	2.64177	.39862	2.50864	.41899	2.38668	.43966	2.27447	16
45	.37887	2.63945	.39896	2.50652	.41933	2.38473	.44001	2.27267	15
46	.37920	2.63714	.39930	2.50440	.41968	2.38279	.44036	2.27088	14
47	.37953	2.63483	.39963	2.50229	.42002	2.38084	.44071	2.26909	13
48	.37986	2.63252	.39997	2.50018	.42036	2.37891	.44105	2.26730	12
49	.38020	2.63021	.40031	2.49807	.42070	2.37697	.44140	2.26552	11
50	.38053	2.62791	.40065	2.49597	.42105	2.37504	.44175	2.26374	10
51	.38086	2.62561	.40098	2.49386	.42139	2.37311	.44210	2.26196	9
52	.38120	2.62332	.40132	2.49177	.42173	2.37118	.44244	2.26018	8
53	.38153	2.62103	.40166	2.48967	.42207	2.36925	.44279	2.25840	7
54	.38186	2.61874	.40200	2.48758	.42242	2.36733	.44314	2.25663	6
55	.38220	2.61646	.40234	2.48549	.42276	2.36541	.44349	2.25486	5
56	.38253	2.61418	.40267	2.48340	.42310	2.36349	.44384	2.25309	4
57	.38286	2.61190	.40301	2.48132	.42345	2.36158	.44418	2.25132	3
58	.38320	2.60963	.40335	2.47924	.42379	2.35967	.44453	2.24956	2
59	.38353	2.60736	.40369	2.47716	.42413	2.35776	.44488	2.24780	1
60	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	0

′	69° Co-tan.	69° Tan.	68° Co-tan.	68° Tan.	67° Co-tan.	67° Tan.	66° Co-tan.	66° Tan.	′

′	24° Tan.	24° Co-tan.	25° Tan.	25° Co-tan.	26° Tan.	26° Co-tan.	27° Tan.	27° Co-tan.	
0	.44523	2.24604	.46631	2.14451	.48773	2.05030	.50953	1.96261	60
1	.44558	2.24428	.46666	2.14288	.48809	2.04879	.50989	1.96120	59
2	.44593	2.24252	.46702	2.14125	.48845	2.04728	.51026	1.95979	58
3	.44627	2.24077	.46737	2.13963	.48881	2.04577	.51063	1.95838	57
4	.44662	2.23902	.46772	2.13801	.48917	2.04426	.51099	1.95698	56
5	.44697	2.23727	.46808	2.13639	.48953	2.04276	.51136	1.95557	55
6	.44732	2.23553	.46843	2.13477	.48989	2.04125	.51173	1.95417	54
7	.44767	2.23378	.46879	2.13316	.49026	2.03975	.51209	1.95277	53
8	.44802	2.23204	.46914	2.13154	.49062	2.03825	.51246	1.95137	52
9	.44837	2.23030	.46950	2.12993	.49098	2.03675	.51283	1.94997	51
10	.44872	2.22857	.46985	2.12832	.49134	2.03526	.51319	1.94858	50
11	.44907	2.22683	.47021	2.12671	.49170	2.03376	.51356	1.94718	49
12	.44942	2.22510	.47056	2.12511	.49206	2.03227	.51393	1.94579	48
13	.44977	2.22337	.47092	2.12350	.49242	2.03078	.51430	1.94440	47
14	.45012	2.22164	.47128	2.12190	.49278	2.02929	.51467	1.94301	46
15	.45047	2.21992	.47163	2.12030	.49315	2.02780	.51503	1.94162	45
16	.45082	2.21819	.47199	2.11871	.49351	2.02631	.51540	1.94023	44
17	.45117	2.21647	.47234	2.11711	.49387	2.02483	.51577	1.93885	43
18	.45152	2.21475	.47270	2.11552	.49423	2.02335	.51614	1.93746	42
19	.45187	2.21304	.47305	2.11392	.49459	2.02187	.51651	1.93608	41
20	.45222	2.21132	.47341	2.11233	.49495	2.02039	.51688	1.93470	40
21	.45257	2.20961	.47377	2.11075	.49532	2.01891	.51724	1.93332	39
22	.45292	2.20790	.47412	2.10916	.49568	2.01743	.51761	1.93195	38
23	.45327	2.20619	.47448	2.10758	.49604	2.01596	.51798	1.93057	37
24	.45362	2.20449	.47483	2.10600	.49640	2.01449	.51835	1.92920	36
25	.45397	2.20278	.47519	2.10442	.49677	2.01302	.51872	1.92782	35
26	.45432	2.20108	.47555	2.10284	.49713	2.01155	.51909	1.92645	34
27	.45467	2.19938	.47590	2.10126	.49749	2.01008	.51946	1.92508	33
28	.45502	2.19769	.47626	2.09969	.49786	2.00862	.51983	1.92371	32
29	.45537	2.19599	.47662	2.09811	.49822	2.00715	.52020	1.92235	31
30	.45573	2.19430	.47698	2.09654	.49858	2.00569	.52057	1.92098	30
31	.45608	2.19261	.47733	2.09498	.49894	2.00423	.52094	1.91962	29
32	.45643	2.19092	.47769	2.09341	.49931	2.00277	.52131	1.91826	28
33	.45678	2.18923	.47805	2.09184	.49967	2.00131	.52168	1.91690	27
34	.45713	2.18755	.47840	2.09028	.50004	1.99986	.52205	1.91554	26
35	.45748	2.18587	.47876	2.08872	.50040	1.99841	.52242	1.91418	25
36	.45784	2.18419	.47912	2.08716	.50076	1.99695	.52279	1.91282	24
37	.45819	2.18251	.47948	2.08560	.50113	1.99550	.52316	1.91147	23
38	.45854	2.18084	.47984	2.08405	.50149	1.99406	.52353	1.91012	22
39	.45889	2.17916	.48019	2.08250	.50185	1.99261	.52390	1.90876	21
40	.45924	2.17749	.48055	2.08094	.50222	1.99116	.52427	1.90741	20
41	.45960	2.17582	.48091	2.07939	.50258	1.98972	.52464	1.90607	19
42	.45995	2.17416	.48127	2.07785	.50295	1.98828	.52501	1.90472	18
43	.46030	2.17249	.48163	2.07630	.50331	1.98684	.52538	1.90337	17
44	.46065	2.17083	.48198	2.07476	.50368	1.98540	.52575	1.90203	16
45	.46101	2.16917	.48234	2.07321	.50404	1.98396	.52613	1.90069	15
46	.46136	2.16751	.48270	2.07167	.50441	1.98253	.52650	1.89935	14
47	.46171	2.16585	.48306	2.07014	.50477	1.98110	.52687	1.89801	13
48	.46206	2.16420	.48342	2.06860	.50514	1.97966	.52724	1.89667	12
49	.46242	2.16255	.48378	2.06706	.50550	1.97823	.52761	1.89533	11
50	.46277	2.16090	.48414	2.06553	.50587	1.97680	.52798	1.89400	10
51	.46312	2.15925	.48450	2.06400	.50623	1.97538	.52836	1.89266	9
52	.46348	2.15760	.48486	2.06247	.50660	1.97395	.52873	1.89133	8
53	.46383	2.15596	.48521	2.06094	.50696	1.97253	.52910	1.89000	7
54	.46418	2.15432	.48557	2.05942	.50733	1.97111	.52947	1.88867	6
55	.46454	2.15268	.48593	2.05790	.50769	1.96969	.52984	1.88734	5
56	.46489	2.15104	.48629	2.05637	.50806	1.96827	.53022	1.88602	4
57	.46525	2.14940	.48665	2.05485	.50843	1.96685	.53059	1.88469	3
58	.46560	2.14777	.48701	2.05333	.50879	1.96544	.53096	1.88337	2
59	.46595	2.14614	.48737	2.05182	.50916	1.96402	.53134	1.88205	1
60	.46631	2.14451	.48773	2.05030	.50953	1.96261	.53171	1.88073	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	65°		64°		63°		62°		

	28°		29°		30°		31°		
	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	
0	.53171	1.88073	.55431	1.80405	.57735	1.73205	.60086	1.66428	60
1	.53208	1.87941	.55469	1.80281	.57774	1.73089	.60126	1.66318	59
2	.53246	1.87809	.55507	1.80158	.57813	1.72973	.60165	1.66209	58
3	.53283	1.87677	.55545	1.80034	.57851	1.72857	.60205	1.66099	57
4	.53320	1.87546	.55583	1.79911	.57890	1.72741	.60245	1.65990	56
5	.53358	1.87415	.55621	1.79788	.57929	1.72625	.60284	1.65881	55
6	.53395	1.87283	.55659	1.79665	.57968	1.72509	.60324	1.65772	54
7	.53432	1.87152	.55697	1.79542	.58007	1.72393	.60364	1.65663	53
8	.53470	1.87021	.55736	1.79419	.58046	1.72278	.60403	1.65554	52
9	.53507	1.86891	.55774	1.79296	.58085	1.72163	.60443	1.65445	51
10	.53545	1.86760	.55812	1.79174	.58124	1.72047	.60483	1.65337	50
11	.53582	1.86630	.55850	1.79051	.58162	1.71932	.60522	1.65228	49
12	.53620	1.86499	.55888	1.78929	.58201	1.71817	.60562	1.65120	48
13	.53657	1.86369	.55926	1.78807	.58240	1.71702	.60602	1.65011	47
14	.53694	1.86239	.55964	1.78685	.58279	1.71588	.60642	1.64903	46
15	.53732	1.86109	.56003	1.78563	.58318	1.71473	.60681	1.64795	45
16	.53769	1.85979	.56041	1.78441	.58357	1.71358	.60721	1.64687	44
17	.53807	1.85850	.56079	1.78319	.58396	1.71244	.60761	1.64579	43
18	.53844	1.85720	.56117	1.78198	.58435	1.71129	.60801	1.64471	42
19	.53882	1.85591	.56156	1.78077	.58474	1.71015	.60841	1.64363	41
20	.53920	1.85462	.56194	1.77955	.58513	1.70901	.60881	1.64256	40
21	.53957	1.85333	.56232	1.77834	.58552	1.70787	.60921	1.64148	39
22	.53995	1.85204	.56270	1.77713	.58591	1.70673	.60960	1.64041	38
23	.54032	1.85075	.56309	1.77592	.58631	1.70560	.61000	1.63934	37
24	.54070	1.84946	.56347	1.77471	.58670	1.70446	.61040	1.63826	36
25	.54107	1.84818	.56385	1.77351	.58709	1.70332	.61080	1.63719	35
26	.54145	1.84689	.56424	1.77230	.58748	1.70219	.61120	1.63612	34
27	.54183	1.84561	.56462	1.77110	.58787	1.70106	.61160	1.63505	33
28	.54220	1.84433	.56500	1.76990	.58826	1.69992	.61200	1.63398	32
29	.54258	1.84305	.56539	1.76869	.58865	1.69879	.61240	1.63292	31
30	.54296	1.84177	.56577	1.76749	.58904	1.69766	.61280	1.63185	30
31	.54333	1.84049	.56616	1.76630	.58944	1.69653	.61320	1.63079	29
32	.54371	1.83922	.56654	1.76510	.58983	1.69541	.61360	1.62972	28
33	.54409	1.83794	.56693	1.76390	.59022	1.69428	.61400	1.62866	27
34	.54446	1.83667	.56731	1.76271	.59061	1.69316	.61440	1.62760	26
35	.54484	1.83540	.56769	1.76151	.59101	1.69203	.61480	1.62654	25
36	.54522	1.83413	.56808	1.76032	.59140	1.69091	.61520	1.62548	24
37	.54560	1.83286	.56846	1.75913	.59179	1.68979	.61561	1.62442	23
38	.54597	1.83159	.56885	1.75794	.59218	1.68866	.61601	1.62336	22
39	.54635	1.83033	.56923	1.75675	.59258	1.68754	.61641	1.62230	21
40	.54673	1.82906	.56962	1.75556	.59297	1.68643	.61681	1.62125	20
41	.54711	1.82780	.57000	1.75437	.59336	1.68531	.61721	1.62019	19
42	.54748	1.82654	.57039	1.75319	.59376	1.68419	.61761	1.61914	18
43	.54786	1.82528	.57078	1.75200	.59415	1.68308	.61801	1.61808	17
44	.54824	1.82402	.57116	1.75082	.59454	1.68196	.61842	1.61703	16
45	.54862	1.82276	.57155	1.74964	.59494	1.68085	.61882	1.61598	15
46	.54900	1.82150	.57193	1.74846	.59533	1.67974	.61922	1.61493	14
47	.54938	1.82025	.57232	1.74728	.59573	1.67863	.61962	1.61388	13
48	.54975	1.81899	.57271	1.74610	.59612	1.67752	.62003	1.61283	12
49	.55013	1.81774	.57309	1.74492	.59651	1.67641	.62043	1.61179	11
50	.55051	1.81649	.57348	1.74375	.59691	1.67530	.62083	1.61074	10
51	.55089	1.81524	.57386	1.74257	.59730	1.67419	.62124	1.60970	9
52	.55127	1.81399	.57425	1.74140	.59770	1.67309	.62164	1.60865	8
53	.55165	1.81274	.57464	1.74022	.59809	1.67198	.62204	1.60761	7
54	.55203	1.81150	.57503	1.73905	.59849	1.67088	.62245	1.60657	6
55	.55241	1.81025	.57541	1.73788	.59888	1.66978	.62285	1.60553	5
56	.55279	1.80901	.57580	1.73671	.59928	1.66867	.62325	1.60449	4
57	.55317	1.80777	.57619	1.73555	.59967	1.66757	.62366	1.60345	3
58	.55355	1.80653	.57657	1.73438	.60007	1.66647	.62406	1.60241	2
59	.55393	1.80529	.57696	1.73321	.60046	1.66538	.62446	1.60137	1
60	.55431	1.80405	.57735	1.73205	.60086	1.66428	.62487	1.60033	0
	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	
	61°		60°		59°		58°		

′	32° Tan.	32° Co-tan.	33° Tan.	33° Co-tan.	34° Tan.	34° Co-tan.	35° Tan.	35° Co-tan.	′
0	.62487	1.60033	.64941	1.53986	.67451	1.48256	.70021	1.42815	60
1	.62527	1.59930	.64982	1.53888	.67493	1.48163	.70064	1.42726	59
2	.62568	1.59826	.65023	1.53791	.67536	1.48070	.70107	1.42638	58
3	.62608	1.59723	.65065	1.53693	.67578	1.47977	.70151	1.42550	57
4	.62649	1.59620	.65106	1.53595	.67620	1.47885	.70194	1.42462	56
5	.62689	1.59517	.65148	1.53497	.67663	1.47792	.70238	1.42374	55
6	.62730	1.59414	.65189	1.53400	.67705	1.47699	.70281	1.42286	54
7	.62770	1.59311	.65231	1.53302	.67748	1.47607	.70325	1.42198	53
8	.62811	1.59208	.65272	1.53205	.67790	1.47514	.70368	1.42110	52
9	.62852	1.59105	.65314	1.53107	.67832	1.47422	.70412	1.42022	51
10	.62892	1.59002	.65355	1.53010	.67875	1.47330	.70455	1.41934	50
11	.62933	1.58900	.65397	1.52913	.67917	1.47238	.70499	1.41847	49
12	.62973	1.58797	.65438	1.52816	.67960	1.47146	.70542	1.41759	48
13	.63014	1.58695	.65480	1.52719	.68002	1.47053	.70586	1.41672	47
14	.63055	1.58593	.65521	1.52622	.68045	1.46962	.70629	1.41584	46
15	.63095	1.58490	.65563	1.52525	.68088	1.46870	.70673	1.41497	45
16	.63136	1.58388	.65604	1.52429	.68130	1.46778	.70717	1.41409	44
17	.63177	1.58286	.65646	1.52332	.68173	1.46686	.70760	1.41322	43
18	.63217	1.58184	.65688	1.52235	.68215	1.46595	.70804	1.41235	42
19	.63258	1.58083	.65729	1.52139	.68258	1.46503	.70848	1.41148	41
20	.63299	1.57981	.65771	1.52043	.68301	1.46411	.70891	1.41061	40
21	.63340	1.57879	.65813	1.51946	.68343	1.46320	.70935	1.40974	39
22	.63380	1.57778	.65854	1.51850	.68386	1.46229	.70979	1.40887	38
23	.63421	1.57676	.65896	1.51754	.68429	1.46137	.71023	1.40800	37
24	.63462	1.57575	.65938	1.51658	.68471	1.46046	.71066	1.40714	36
25	.63503	1.57474	.65980	1.51562	.68514	1.45955	.71110	1.40627	35
26	.63544	1.57372	.66021	1.51466	.68557	1.45864	.71154	1.40540	34
27	.63584	1.57271	.66063	1.51370	.68600	1.45773	.71198	1.40454	33
28	.63625	1.57170	.66105	1.51275	.68642	1.45682	.71242	1.40367	32
29	.63666	1.57069	.66147	1.51179	.68685	1.45592	.71285	1.40281	31
30	.63707	1.56969	.66189	1.51084	.68728	1.45501	.71329	1.40195	30
31	.63748	1.56868	.66230	1.50988	.68771	1.45410	.71373	1.40109	29
32	.63789	1.56767	.66272	1.50893	.68814	1.45320	.71417	1.40022	28
33	.63830	1.56667	.66314	1.50797	.68857	1.45229	.71461	1.39936	27
34	.63871	1.56566	.66356	1.50702	.68900	1.45139	.71505	1.39850	26
35	.63912	1.56466	.66398	1.50607	.68942	1.45049	.71549	1.39764	25
36	.63953	1.56366	.66440	1.50512	.68985	1.44958	.71593	1.39679	24
37	.63994	1.56265	.66482	1.50417	.69028	1.44868	.71637	1.39593	23
38	.64035	1.56165	.66524	1.50322	.69071	1.44778	.71681	1.39507	22
39	.64076	1.56065	.66566	1.50228	.69114	1.44688	.71725	1.39421	21
40	.64117	1.55966	.66608	1.50133	.69157	1.44598	.71769	1.39336	20
41	.64158	1.55866	.66650	1.50038	.69200	1.44508	.71813	1.39250	19
42	.64199	1.55766	.66692	1.49944	.69243	1.44418	.71857	1.39165	18
43	.64240	1.55666	.66734	1.49849	.69286	1.44329	.71901	1.39079	17
44	.64281	1.55567	.66776	1.49755	.69329	1.44239	.71946	1.38994	16
45	.64322	1.55467	.66818	1.49661	.69372	1.44149	.71990	1.38909	15
46	.64363	1.55368	.66860	1.49566	.69416	1.44060	.72034	1.38824	14
47	.64404	1.55269	.66902	1.49472	.69459	1.43970	.72078	1.38738	13
48	.64446	1.55170	.66944	1.49378	.69502	1.43881	.72122	1.38653	12
49	.64487	1.55071	.66986	1.49284	.69545	1.43792	.72166	1.38568	11
50	.64528	1.54972	.67028	1.49190	.69588	1.43703	.72211	1.38484	10
51	.64569	1.54873	.67071	1.49097	.69631	1.43614	.72255	1.38399	9
52	.64610	1.54774	.67113	1.49003	.69675	1.43525	.72299	1.38314	8
53	.64652	1.54675	.67155	1.48909	.69718	1.43436	.72344	1.38229	7
54	.64693	1.54576	.67197	1.48816	.69761	1.43347	.72388	1.38145	6
55	.64734	1.54478	.67239	1.48722	.69804	1.43258	.72432	1.38060	5
56	.64775	1.54379	.67282	1.48629	.69847	1.43169	.72477	1.37976	4
57	.64817	1.54281	.67324	1.48536	.69891	1.43080	.72521	1.37891	3
58	.64858	1.54183	.67366	1.48442	.69934	1.42992	.72565	1.37807	2
59	.64899	1.54085	.67409	1.48349	.69977	1.42903	.72610	1.37722	1
60	.64941	1.53986	.67451	1.48256	.70021	1.42815	.72654	1.37638	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	57°		56°		55°		54°		

′	36°		37°		38°		39°	
	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.
0	.72654	1.37638	.75355	1.32704	.78129	1.27904	.80978	1.23490
1	.72699	1.37554	.75401	1.32624	.78175	1.27917	.81027	1.23416
2	.72743	1.37470	.75447	1.32544	.78222	1.27841	.81075	1.23343
3	.72788	1.37386	.75492	1.32464	.78269	1.27764	.81123	1.23270
4	.72832	1.37302	.75538	1.32384	.78316	1.27688	.81171	1.23196
5	.72877	1.37218	.75584	1.32304	.78363	1.27611	.81220	1.23123
6	.72921	1.37134	.75629	1.32224	.78410	1.27535	.81268	1.23050
7	.72966	1.37050	.75675	1.32144	.78457	1.27458	.81316	1.22977
8	.73010	1.36967	.75721	1.32064	.78504	1.27382	.81364	1.22904
9	.73055	1.36883	.75767	1.31984	.78551	1.27306	.81413	1.22831
10	.73100	1.36800	.75812	1.31904	.78598	1.27230	.81461	1.22758
11	.73144	1.36716	.75858	1.31825	.78645	1.27153	.81510	1.22685
12	.73189	1.36633	.75904	1.31745	.78692	1.27077	.81558	1.22612
13	.73234	1.36549	.75950	1.31666	.78739	1.27001	.81606	1.22539
14	.73278	1.36466	.75996	1.31586	.78786	1.26925	.81655	1.22467
15	.73323	1.36383	.76042	1.31507	.78834	1.26849	.81703	1.22394
16	.73368	1.36300	.76088	1.31427	.78881	1.26774	.81752	1.22321
17	.73413	1.36217	.76134	1.31348	.78928	1.26698	.81800	1.22249
18	.73457	1.36133	.76180	1.31269	.78975	1.26622	.81849	1.22176
19	.73502	1.36051	.76226	1.31190	.79022	1.26546	.81898	1.22104
20	.73547	1.35968	.76272	1.31110	.79070	1.26471	.81946	1.22031
21	.73592	1.35885	.76318	1.31031	.79117	1.26395	.81995	1.21959
22	.73637	1.35802	.76364	1.30952	.79164	1.26319	.82044	1.21886
23	.73681	1.35719	.76410	1.30873	.79212	1.26244	.82092	1.21814
24	.73726	1.35637	.76456	1.30795	.79259	1.26169	.82141	1.21742
25	.73771	1.35554	.76502	1.30716	.79306	1.26093	.82190	1.21670
26	.73816	1.35472	.76548	1.30637	.79354	1.26018	.82238	1.21598
27	.73861	1.35389	.76594	1.30558	.79401	1.25943	.82287	1.21526
28	.73906	1.35307	.76640	1.30480	.79449	1.25867	.82336	1.21454
29	.73951	1.35224	.76686	1.30401	.79496	1.25792	.82385	1.21382
30	.73996	1.35142	.76733	1.30323	.79544	1.25717	.82434	1.21310
31	.74041	1.35060	.76779	1.30244	.79591	1.25642	.82483	1.21238
32	.74086	1.34978	.76825	1.30166	.79639	1.25567	.82531	1.21166
33	.74131	1.34896	.76871	1.30087	.79686	1.25492	.82580	1.21094
34	.74176	1.34814	.76918	1.30009	.79734	1.25417	.82629	1.21023
35	.74221	1.34732	.76964	1.29931	.79781	1.25343	.82678	1.20951
36	.74267	1.34650	.77010	1.29853	.79829	1.25268	.82727	1.20879
37	.74312	1.34568	.77057	1.29775	.79877	1.25193	.82776	1.20808
38	.74357	1.34487	.77103	1.29696	.79924	1.25118	.82825	1.20736
39	.74402	1.34405	.77149	1.29618	.79972	1.25044	.82874	1.20665
40	.74447	1.34323	.77196	1.29541	.80020	1.24969	.82923	1.20593
41	.74492	1.34242	.77242	1.29463	.80067	1.24895	.82972	1.20522
42	.74538	1.34160	.77289	1.29385	.80115	1.24820	.83022	1.20451
43	.74583	1.34079	.77335	1.29307	.80163	1.24746	.83071	1.20379
44	.74628	1.33998	.77382	1.29229	.80211	1.24672	.83120	1.20308
45	.74674	1.33916	.77428	1.29152	.80258	1.24597	.83169	1.20237
46	.74719	1.33835	.77475	1.29074	.80306	1.24523	.83218	1.20166
47	.74764	1.33754	.77521	1.28997	.80354	1.24449	.83268	1.20095
48	.74810	1.33673	.77568	1.28919	.80402	1.24375	.83317	1.20024
49	.74855	1.33592	.77615	1.28842	.80450	1.24301	.83366	1.19953
50	.74900	1.33511	.77661	1.28764	.80498	1.24227	.83415	1.19882
51	.74946	1.33430	.77708	1.28687	.80546	1.24153	.83465	1.19811
52	.74991	1.33349	.77754	1.28610	.80594	1.24079	.83514	1.19740
53	.75037	1.33268	.77801	1.28533	.80642	1.24005	.83564	1.19669
54	.75082	1.33187	.77848	1.28456	.80690	1.23931	.83613	1.19599
55	.75128	1.33107	.77895	1.28379	.80738	1.23858	.83662	1.19528
56	.75173	1.33026	.77941	1.28302	.80786	1.23784	.83712	1.19457
57	.75219	1.32946	.77988	1.28225	.80834	1.23710	.83761	1.19387
58	.75264	1.32865	.78035	1.28148	.80882	1.23637	.83811	1.19316
59	.75310	1.32785	.78082	1.28071	.80930	1.23563	.83860	1.19246
60	.75355	1.32704	.78129	1.27994	.80978	1.23490	.83910	1.19175
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.
	53°		52°		51°		50°	

40°		41°		42°		43°		
Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	′
.83910	1.19175	.86929	1.15037	.90040	1.11061	.93252	1.07237	60
.83960	1.19105	.86980	1.14969	.90093	1.10996	.93306	1.07174	59
.84009	1.19035	.87031	1.14902	.90146	1.10931	.93360	1.07112	58
.84059	1.18964	.87082	1.14834	.90199	1.10867	.93415	1.07049	57
.84108	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	56
.84158	1.18824	.87184	1.14699	.90304	1.10737	.93524	1.06925	55
.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	54
.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	53
.84307	1.18614	.87338	1.14498	.90463	1.10543	.93688	1.06738	52
.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	51
.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	50
.84457	1.18404	.87492	1.14296	.90621	1.10349	.93852	1.06551	49
.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906	1.06489	48
.84556	1.18264	.87595	1.14162	.90727	1.10220	.93961	1.06427	47
.84606	1.18194	.87646	1.14095	.90781	1.10156	.94016	1.06365	46
.84656	1.18125	.87698	1.14028	.90834	1.10091	.94071	1.06303	45
.84706	1.18055	.87749	1.13961	.90887	1.10027	.94125	1.06241	44
.84756	1.17986	.87801	1.13894	.90940	1.09963	.94180	1.06179	43
.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	42
.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	41
.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	40
.84956	1.17708	.88007	1.13627	.91153	1.09706	.94400	1.05932	39
.85006	1.17638	.88059	1.13561	.91206	1.09642	.94455	1.05870	38
.85057	1.17569	.88110	1.13494	.91259	1.09578	.94510	1.05809	37
.85107	1.17500	.88162	1.13428	.91313	1.09514	.94565	1.05747	36
.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	35
.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1.05624	34
.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	33
.85307	1.17223	.88369	1.13162	.91526	1.09258	.94786	1.05501	32
.85358	1.17154	.88421	1.13096	.91580	1.09195	.94841	1.05439	31
.85408	1.17085	.88473	1.13029	.91633	1.09131	.94896	1.05378	30
.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05317	29
.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	28
.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	27
.85609	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	26
.85660	1.16741	.88732	1.12699	.91901	1.08813	.95173	1.05072	25
.85710	1.16672	.88784	1.12633	.91955	1.08749	.95229	1.05010	24
.85761	1.16603	.88836	1.12567	.92008	1.08686	.95284	1.04949	23
.85811	1.16535	.88888	1.12501	.92062	1.08622	.95340	1.04888	22
.85862	1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	21
.85912	1.16398	.88992	1.12369	.92170	1.08496	.95451	1.04766	20
.85963	1.16329	.89045	1.12303	.92224	1.08432	.95506	1.04705	19
.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	18
.86064	1.16192	.89149	1.12172	.92331	1.08306	.95618	1.04583	17
.86115	1.16124	.89201	1.12106	.92385	1.08243	.95673	1.04522	16
.86166	1.16056	.89253	1.12041	.92439	1.08179	.95729	1.04461	15
.86216	1.15987	.89306	1.11975	.92493	1.08116	.95785	1.04401	14
.86267	1.15919	.89358	1.11909	.92547	1.08053	.95841	1.04340	13
.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	12
.86368	1.15783	.89463	1.11778	.92655	1.07927	.95952	1.04218	11
.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	10
.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	9
.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04036	8
.86572	1.15511	.89672	1.11517	.92872	1.07676	.96176	1.03976	7
.86623	1.15443	.89725	1.11452	.92926	1.07613	.96232	1.03915	6
.86674	1.15375	.89777	1.11387	.92980	1.07550	.96288	1.03855	5
.86725	1.15308	.89830	1.11321	.93034	1.07487	.96344	1.03794	4
.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1.03734	3
.86827	1.15172	.89935	1.11191	.93143	1.07362	.96457	1.03674	2
.86878	1.15104	.89988	1.11126	.93197	1.07299	.96513	1.03613	1
.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	0
Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
49°		48°		47°		46°		

′	44° Tan.	44° Co-tan.	′	′	44° Tan.	44° Co-tan.	′	′	44° Tan.	44° Co-tan.	′
0	.96569	1.03553	60	21	.97756	1.02295	39	41	.98901	1.01112	19
1	.96625	1.03493	59	22	.97813	1.02236	38	42	.98958	1.01053	18
2	.96681	1.03433	58	23	.97870	1.02176	37	43	.99016	1.00994	17
3	.96738	1.03372	57	24	.97927	1.02117	36	44	.99073	1.00935	16
4	.96794	1.03312	56	25	.97984	1.02057	35	45	.99131	1.00876	15
5	.96850	1.03252	55	26	.98041	1.01998	34	46	.99189	1.00818	14
6	.96907	1.03192	54	27	.98098	1.01939	33	47	.99247	1.00759	13
7	.96963	1.03132	53	28	.98155	1.01879	32	48	.99304	1.00701	12
8	.97020	1.03072	52	29	.98213	1.01820	31	49	.99362	1.00642	11
9	.97076	1.03012	51	30	.98270	1.01761	30	50	.99420	1.00583	10
10	.97133	1.02952	50	31	.98327	1.01702	29	51	.99478	1.00525	9
11	.97189	1.02892	49	32	.98384	1.01642	28	52	.99536	1.00467	8
12	.97246	1.02832	48	33	.98441	1.01583	27	53	.99594	1.00408	7
13	.97302	1.02772	47	34	.98499	1.01524	26	54	.99652	1.00350	6
14	.97359	1.02713	46	35	.98556	1.01465	25	55	.99710	1.00291	5
15	.97416	1.02653	45	36	.98613	1.01406	24	56	.99768	1.00233	4
16	.97472	1.02593	44	37	.98671	1.01347	23	57	.99826	1.00175	3
17	.97529	1.02533	43	38	.98728	1.01288	22	58	.99884	1.00116	2
18	.97586	1.02474	42	39	.98786	1.01229	21	59	.99942	1.00058	1
19	.97643	1.02414	41	40	.98843	1.01170	20	60	1	1	0
20	.97700	1.02355	40								
′	Co-tan. 45°	Tan.	′	′	Co-tan. 45°	Tan.	′	′	Co-tan. 45°	Tan.	′

NATURAL SINES AND COSINES

′	0° Sine	0° Cosine	′	′	0° Sine	0° Cosine	′	′	0° Sine	0° Cosine	′
0	.00000	1	60	21	.00611	.99998	39	41	.01193	.99993	1
1	.00029	1	59	22	.00640	.99998	38	42	.01222	.99993	1
2	.00058	1	58	23	.00669	.99998	37	43	.01251	.99992	1
3	.00087	1	57	24	.00698	.99998	36	44	.01280	.99992	1
4	.00116	1	56	25	.00727	.99997	35	45	.01309	.99991	1
5	.00145	1	55	26	.00756	.99997	34	46	.01338	.99991	1
6	.00175	1	54	27	.00785	.99997	33	47	.01367	.99991	1
7	.00204	1	53	28	.00814	.99997	32	48	.01396	.99990	1
8	.00233	1	52	29	.00844	.99996	31	49	.01425	.99990	1
9	.00262	1	51	30	.00873	.99996	30	50	.01454	.99989	1
10	.00291	1	50	31	.00902	.99996	29	51	.01483	.99989	
11	.00320	.99999	49	32	.00931	.99996	28	52	.01513	.99989	
12	.00349	.99999	48	33	.00960	.99995	27	53	.01542	.99988	
13	.00378	.99999	47	34	.00989	.99995	26	54	.01571	.99988	
14	.00407	.99999	46	35	.01018	.99995	25	55	.01600	.99987	
15	.00436	.99999	45	36	.01047	.99995	24	56	.01629	.99987	
16	.00465	.99999	44	37	.01076	.99994	23	57	.01658	.99986	
17	.00495	.99999	43	38	.01105	.99994	22	58	.01687	.99986	
18	.00524	.99999	42	39	.01134	.99994	21	59	.01716	.99985	
19	.00553	.99998	41	40	.01164	.99993	20	60	.01745	.99985	
20	.00582	.99998	40								
′	Cosine 89°	Sine	′	′	Cosine 89°	Sine	′	′	Cosine 89°	Sine	′

′	1° Sine	1° Cosine	2° Sine	2° Cosine	3° Sine	3° Cosine	4° Sine	4° Cosine	′
0	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	60
1	.01774	.99984	.03519	.99938	.05263	.99861	.07005	.99754	59
2	.01803	.99984	.03548	.99937	.05292	.99860	.07034	.99752	58
3	.01832	.99983	.03577	.99936	.05321	.99858	.07063	.99750	57
4	.01862	.99983	.03606	.99935	.05350	.99857	.07092	.99748	56
5	.01891	.99982	.03635	.99934	.05379	.99855	.07121	.99746	55
6	.01920	.99982	.03664	.99933	.05408	.99854	.07150	.99744	54
7	.01949	.99981	.03693	.99932	.05437	.99852	.07179	.99742	53
8	.01978	.99980	.03723	.99931	.05466	.99851	.07208	.99740	52
9	.02007	.99980	.03752	.99930	.05495	.99849	.07237	.99738	51
10	.02036	.99979	.03781	.99929	.05524	.99847	.07266	.99736	50
11	.02065	.99979	.03810	.99927	.05553	.99846	.07295	.99734	49
12	.02094	.99978	.03839	.99926	.05582	.99844	.07324	.99731	48
13	.02123	.99977	.03868	.99925	.05611	.99842	.07353	.99729	47
14	.02152	.99977	.03897	.99924	.05640	.99841	.07382	.99727	46
15	.02181	.99976	.03926	.99923	.05669	.99839	.07411	.99725	45
16	.02211	.99976	.03955	.99922	.05698	.99838	.07440	.99723	44
17	.02240	.99975	.03984	.99921	.05727	.99836	.07469	.99721	43
18	.02269	.99974	.04013	.99919	.05756	.99834	.07498	.99719	42
19	.02298	.99974	.04042	.99918	.05785	.99833	.07527	.99716	41
20	.02327	.99973	.04071	.99917	.05814	.99831	.07556	.99714	40
21	.02356	.99972	.04100	.99916	.05844	.99829	.07585	.99712	39
22	.02385	.99972	.04129	.99915	.05873	.99827	.07614	.99710	38
23	.02414	.99971	.04159	.99913	.05902	.99826	.07643	.99708	37
24	.02443	.99970	.04188	.99912	.05931	.99824	.07672	.99705	36
25	.02472	.99969	.04217	.99911	.05960	.99822	.07701	.99703	35
26	.02501	.99969	.04246	.99910	.05989	.99821	.07730	.99701	34
27	.02530	.99968	.04275	.99909	.06018	.99819	.07759	.99699	33
28	.02560	.99967	.04304	.99907	.06047	.99817	.07788	.99696	32
29	.02589	.99966	.04333	.99906	.06076	.99815	.07817	.99694	31
30	.02618	.99966	.04362	.99905	.06105	.99813	.07846	.99692	30
31	.02647	.99965	.04391	.99904	.06134	.99812	.07875	.99689	29
32	.02676	.99964	.04420	.99902	.06163	.99810	.07904	.99687	28
33	.02705	.99963	.04449	.99901	.06192	.99808	.07933	.99685	27
34	.02734	.99963	.04478	.99900	.06221	.99806	.07962	.99683	26
35	.02763	.99962	.04507	.99898	.06250	.99804	.07991	.99680	25
36	.02792	.99961	.04536	.99897	.06279	.99803	.08020	.99678	24
37	.02821	.99960	.04565	.99896	.06308	.99801	.08049	.99676	23
38	.02850	.99959	.04594	.99894	.06337	.99799	.08078	.99673	22
39	.02879	.99959	.04623	.99893	.06366	.99797	.08107	.99671	21
40	.02908	.99958	.04653	.99892	.06395	.99795	.08136	.99668	20
41	.02938	.99957	.04682	.99890	.06424	.99793	.08165	.99666	19
42	.02967	.99956	.04711	.99889	.06453	.99792	.08194	.99664	18
43	.02996	.99955	.04740	.99888	.06482	.99790	.08223	.99661	17
44	.03025	.99954	.04769	.99886	.06511	.99788	.08252	.99659	16
45	.03054	.99953	.04798	.99885	.06540	.99786	.08281	.99657	15
46	.03083	.99952	.04827	.99883	.06569	.99784	.08310	.99654	14
47	.03112	.99952	.04856	.99882	.06598	.99782	.08339	.99652	13
48	.03141	.99951	.04885	.99881	.06627	.99780	.08368	.99649	12
49	.03170	.99950	.04914	.99879	.06656	.99778	.08397	.99647	11
50	.03199	.99949	.04943	.99878	.06685	.99776	.08426	.99644	10
51	.03228	.99948	.04972	.99876	.06714	.99774	.08455	.99642	9
52	.03257	.99947	.05001	.99875	.06743	.99772	.08484	.99639	8
53	.03286	.99946	.05030	.99873	.06773	.99770	.08513	.99637	7
54	.03316	.99945	.05059	.99872	.06802	.99768	.08542	.99635	6
55	.03345	.99944	.05088	.99870	.06831	.99766	.08571	.99632	5
56	.03374	.99943	.05117	.99869	.06860	.99764	.08600	.99630	4
57	.03403	.99942	.05146	.99867	.06889	.99762	.08629	.99627	3
58	.03432	.99941	.05175	.99866	.06918	.99760	.08658	.99625	2
59	.03461	.99940	.05205	.99864	.06947	.99758	.08687	.99622	1
60	.03490	.99939	.05234	.99863	.06976	.99756	.08716	.99619	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	88°		87°		86°		85°		

′	5° Sine	5° Cosine	6° Sine	6° Cosine	7° Sine	7° Cosine	8° Sine	8° Cosine	′
0	.08716	.99619	.10453	.99452	.12187	.99255	.13917	.99027	60
1	.08745	.99617	.10482	.99449	.12216	.99251	.13946	.99023	59
2	.08774	.99614	.10511	.99446	.12245	.99248	.13975	.99019	58
3	.08803	.99612	.10540	.99443	.12274	.99244	.14004	.99015	57
4	.08831	.99609	.10569	.99440	.12302	.99240	.14033	.99011	56
5	.08860	.99607	.10597	.99437	.12331	.99237	.14061	.99006	55
6	.08889	.99604	.10626	.99434	.12360	.99233	.14090	.99002	54
7	.08918	.99602	.10655	.99431	.12389	.99230	.14119	.98998	53
8	.08947	.99599	.10684	.99428	.12418	.99226	.14148	.98994	52
9	.08976	.99596	.10713	.99424	.12447	.99222	.14177	.98990	51
10	.09005	.99594	.10742	.99421	.12476	.99219	.14205	.98986	50
11	.09034	.99591	.10771	.99418	.12504	.99215	.14234	.98982	49
12	.09063	.99588	.10800	.99415	.12533	.99211	.14263	.98978	48
13	.09092	.99586	.10829	.99412	.12562	.99208	.14292	.98973	47
14	.09121	.99583	.10858	.99409	.12591	.99204	.14320	.98969	46
15	.09150	.99580	.10887	.99406	.12620	.99200	.14349	.98965	45
16	.09179	.99578	.10916	.99402	.12649	.99197	.14378	.98961	44
17	.09208	.99575	.10945	.99399	.12678	.99193	.14407	.98957	43
18	.09237	.99572	.10973	.99396	.12706	.99189	.14436	.98953	42
19	.09266	.99570	.11002	.99393	.12735	.99186	.14464	.98948	41
20	.09295	.99567	.11031	.99390	.12764	.99182	.14493	.98944	40
21	.09324	.99564	.11060	.99386	.12793	.99178	.14522	.98940	39
22	.09353	.99562	.11089	.99383	.12822	.99175	.14551	.98936	38
23	.09382	.99559	.11118	.99380	.12851	.99171	.14580	.98931	37
24	.09411	.99556	.11147	.99377	.12880	.99167	.14608	.98927	36
25	.09440	.99553	.11176	.99374	.12908	.99163	.14637	.98923	35
26	.09469	.99551	.11205	.99370	.12937	.99160	.14666	.98919	34
27	.09498	.99548	.11234	.99367	.12966	.99156	.14695	.98914	33
28	.09527	.99545	.11263	.99364	.12995	.99152	.14723	.98910	32
29	.09556	.99542	.11291	.99360	.13024	.99148	.14752	.98906	31
30	.09585	.99540	.11320	.99357	.13053	.99144	.14781	.98902	30
31	.09614	.99537	.11349	.99354	.13081	.99141	.14810	.98897	29
32	.09642	.99534	.11378	.99351	.13110	.99137	.14838	.98893	28
33	.09671	.99531	.11407	.99347	.13139	.99133	.14867	.98889	27
34	.09700	.99528	.11436	.99344	.13168	.99129	.14896	.98884	26
35	.09729	.99526	.11465	.99341	.13197	.99125	.14925	.98880	25
36	.09758	.99523	.11494	.99337	.13226	.99122	.14954	.98876	24
37	.09787	.99520	.11523	.99334	.13254	.99118	.14982	.98871	23
38	.09816	.99517	.11552	.99331	.13283	.99114	.15011	.98867	22
39	.09845	.99514	.11580	.99327	.13312	.99110	.15040	.98863	21
40	.09874	.99511	.11609	.99324	.13341	.99106	.15069	.98858	20
41	.09903	.99508	.11638	.99320	.13370	.99102	.15097	.98854	19
42	.09932	.99506	.11667	.99317	.13399	.99098	.15126	.98849	18
43	.09961	.99503	.11696	.99314	.13427	.99094	.15155	.98845	17
44	.09990	.99500	.11725	.99310	.13456	.99091	.15184	.98841	16
45	.10019	.99497	.11754	.99307	.13485	.99087	.15212	.98836	15
46	.10048	.99494	.11783	.99303	.13514	.99083	.15241	.98832	14
47	.10077	.99491	.11812	.99300	.13543	.99079	.15270	.98827	13
48	.10106	.99488	.11840	.99297	.13572	.99075	.15299	.98823	12
49	.10135	.99485	.11869	.99293	.13600	.99071	.15327	.98818	11
50	.10164	.99482	.11898	.99290	.13629	.99067	.15356	.98814	10
51	.10192	.99479	.11927	.99286	.13658	.99063	.15385	.98809	9
52	.10221	.99476	.11956	.99283	.13687	.99059	.15414	.98805	8
53	.10250	.99473	.11985	.99279	.13716	.99055	.15442	.98800	7
54	.10279	.99470	.12014	.99276	.13744	.99051	.15471	.98796	6
55	.10308	.99467	.12043	.99272	.13773	.99047	.15500	.98791	5
56	.10337	.99464	.12071	.99269	.13802	.99043	.15529	.98787	4
57	.10366	.99461	.12100	.99265	.13831	.99039	.15557	.98782	3
58	.10395	.99458	.12129	.99262	.13860	.99035	.15586	.98778	2
59	.10424	.99455	.12158	.99258	.13889	.99031	.15615	.98773	1
60	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	84°		83°		82°		81°		

′	9° Sine	9° Cosine	10° Sine	10° Cosine	11° Sine	11° Cosine	12° Sine	12° Cosine	′
0	.15643	.98769	.17365	.98481	.19081	.98163	.20791	.97815	60
1	.15672	.98764	.17393	.98476	.19109	.98157	.20820	.97809	59
2	.15701	.98760	.17422	.98471	.19138	.98152	.20848	.97803	58
3	.15730	.98755	.17451	.98466	.19167	.98146	.20877	.97797	57
4	.15758	.98751	.17479	.98461	.19195	.98140	.20905	.97791	56
5	.15787	.98746	.17508	.98455	.19224	.98135	.20933	.97784	55
6	.15816	.98741	.17537	.98450	.19252	.98129	.20962	.97778	54
7	.15845	.98737	.17565	.98445	.19281	.98124	.20990	.97772	53
8	.15873	.98732	.17594	.98440	.19309	.98118	.21019	.97766	52
9	.15902	.98728	.17623	.98435	.19338	.98112	.21047	.97760	51
10	.15931	.98723	.17651	.98430	.19366	.98107	.21076	.97754	50
11	.15959	.98718	.17680	.98425	.19395	.98101	.21104	.97748	49
12	.15988	.98714	.17708	.98420	.19423	.98096	.21132	.97742	48
13	.16017	.98709	.17737	.98414	.19452	.98090	.21161	.97735	47
14	.16046	.98704	.17766	.98409	.19481	.98084	.21189	.97729	46
15	.16074	.98700	.17794	.98404	.19509	.98079	.21218	.97723	45
16	.16103	.98695	.17823	.98399	.19538	.98073	.21246	.97717	44
17	.16132	.98690	.17852	.98394	.19566	.98067	.21275	.97711	43
18	.16160	.98689	.17880	.98389	.19595	.98061	.21303	.97705	42
19	.16189	.98681	.17909	.98383	.19623	.98056	.21331	.97698	41
20	.16218	.98676	.17937	.98378	.19652	.98050	.21360	.97692	40
21	.16246	.98671	.17966	.98373	.19680	.98044	.21388	.97686	39
22	.16275	.98667	.17995	.98368	.19709	.98039	.21417	.97680	38
23	.16304	.98662	.18023	.98362	.19737	.98033	.21445	.97673	37
24	.16333	.98657	.18052	.98357	.19766	.98027	.21474	.97667	36
25	.16361	.98652	.18081	.98352	.19794	.98021	.21502	.97661	35
26	.16390	.98648	.18109	.98347	.19823	.98016	.21530	.97655	34
27	.16419	.98643	.18138	.98341	.19851	.98010	.21559	.97648	33
28	.16447	.98638	.18166	.98336	.19880	.98004	.21587	.97642	32
29	.16476	.98633	.18195	.98331	.19908	.97997	.21616	.97636	31
30	.16505	.98629	.18224	.98325	.19937	.97992	.21644	.97630	30
31	.16533	.98624	.18252	.98320	.19965	.97987	.21672	.97623	29
32	.16562	.98619	.18281	.98315	.19994	.97981	.21701	.97617	28
33	.16591	.98614	.18309	.98310	.20022	.97975	.21729	.97611	27
34	.16620	.98609	.18338	.98304	.20051	.97969	.21758	.97604	26
35	.16648	.98604	.18367	.98299	.20079	.97963	.21786	.97598	25
36	.16677	.98600	.18395	.98294	.20108	.97958	.21814	.97592	24
37	.16706	.98595	.18424	.98288	.20136	.97952	.21843	.97585	23
38	.16734	.98590	.18452	.98283	.20165	.97946	.21871	.97579	22
39	.16763	.98585	.18481	.98277	.20193	.97940	.21899	.97573	21
40	.16792	.98580	.18509	.98272	.20222	.97934	.21928	.97566	20
41	.16820	.98575	.18538	.98267	.20250	.97928	.21956	.97560	19
42	.16849	.98570	.18567	.98261	.20279	.97922	.21985	.97553	18
43	.16878	.98565	.18595	.98256	.20307	.97916	.22013	.97547	17
44	.16906	.98561	.18624	.98250	.20336	.97910	.22041	.97541	16
45	.16935	.98556	.18652	.98245	.20364	.97905	.22070	.97534	15
46	.16964	.98551	.18681	.98240	.20393	.97899	.22098	.97528	14
47	.16992	.98546	.18710	.98234	.20421	.97893	.22126	.97521	13
48	.17021	.98541	.18738	.98229	.20450	.97887	.22155	.97515	12
49	.17050	.98536	.18767	.98223	.20478	.97881	.22183	.97508	11
50	.17078	.98531	.18795	.98218	.20507	.97875	.22212	.97502	10
51	.17107	.98526	.18824	.98212	.20535	.97869	.22240	.97496	9
52	.17136	.98521	.18852	.98207	.20563	.97863	.22268	.97489	8
53	.17164	.98516	.18881	.98201	.20592	.97857	.22297	.97483	7
54	.17193	.98511	.18910	.98196	.20620	.97851	.22325	.97476	6
55	.17222	.98506	.18938	.98190	.20649	.97845	.22353	.97470	5
56	.17250	.98501	.18967	.98185	.20677	.97839	.22382	.97463	4
57	.17279	.98496	.18995	.98179	.20706	.97833	.22410	.97457	3
58	.17308	.98491	.19024	.98174	.20734	.97827	.22438	.97450	2
59	.17336	.98486	.19052	.98168	.20763	.97821	.22467	.97444	1
60	.17365	.98481	.19081	.98163	.20791	.97815	.22495	.97437	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	80°		79°		78°		77°		

′	13° Sine	13° Cosine	14° Sine	14° Cosine	15° Sine	15° Cosine	16° Sine	16° Cosine	′
0	.22495	.97437	.24192	.97030	.25882	.96593	.27564	.96126	60
1	.22523	.97430	.24220	.97023	.25910	.96585	.27592	.96118	59
2	.22552	.97424	.24249	.97015	.25938	.96578	.27620	.96110	58
3	.22580	.97417	.24277	.97008	.25966	.96570	.27648	.96102	57
4	.22608	.97411	.24305	.97001	.25994	.96562	.27676	.96094	56
5	.22637	.97404	.24333	.96994	.26022	.96555	.27704	.96086	55
6	.22665	.97398	.24362	.96987	.26050	.96547	.27731	.96078	54
7	.22693	.97391	.24390	.96980	.26079	.96540	.27759	.96070	53
8	.22722	.97384	.24418	.96973	.26107	.96532	.27787	.96062	52
9	.22750	.97378	.24446	.96966	.26135	.96524	.27815	.96054	51
10	.22778	.97371	.24474	.96959	.26163	.96517	.27843	.96046	50
11	.22807	.97365	.24503	.96952	.26191	.96509	.27871	.96037	49
12	.22835	.97358	.24531	.96945	.26219	.96502	.27899	.96029	48
13	.22863	.97351	.24559	.96937	.26247	.96494	.27927	.96021	47
14	.22892	.97345	.24587	.96930	.26275	.96486	.27955	.96013	46
15	.22920	.97338	.24615	.96923	.26303	.96479	.27983	.96005	45
16	.22948	.97331	.24644	.96916	.26331	.96471	.28011	.95997	44
17	.22977	.97325	.24672	.96909	.26359	.96463	.28039	.95989	43
18	.23005	.97318	.24700	.96902	.26387	.96456	.28067	.95981	42
19	.23033	.97311	.24728	.96894	.26415	.96448	.28095	.95972	41
20	.23062	.97304	.24756	.96887	.26443	.96440	.28123	.95964	40
21	.23090	.97298	.24784	.96880	.26471	.96433	.28150	.95956	39
22	.23118	.97291	.24813	.96873	.26500	.96425	.28178	.95948	38
23	.23146	.97284	.24841	.96866	.26528	.96417	.28206	.95940	37
24	.23175	.97278	.24869	.96858	.26556	.96410	.28234	.95931	36
25	.23203	.97271	.24897	.96851	.26584	.96402	.28262	.95923	35
26	.23231	.97264	.24925	.96844	.26612	.96394	.28290	.95915	34
27	.23260	.97257	.24954	.96837	.26640	.96386	.28318	.95907	33
28	.23288	.97251	.24982	.96829	.26668	.96379	.28346	.95898	32
29	.23316	.97244	.25010	.96822	.26696	.96371	.28374	.95890	31
30	.23345	.97237	.25038	.96815	.26724	.96363	.28402	.95882	30
31	.23373	.97230	.25066	.96807	.26752	.96355	.28429	.95874	29
32	.23401	.97223	.25094	.96800	.26780	.96347	.28457	.95865	28
33	.23429	.97217	.25122	.96793	.26808	.96340	.28485	.95857	27
34	.23458	.97210	.25151	.96786	.26836	.96332	.28513	.95849	26
35	.23486	.97203	.25179	.96778	.26864	.96324	.28541	.95841	25
36	.23514	.97196	.25207	.96771	.26892	.96316	.28569	.95832	24
37	.23542	.97189	.25235	.96764	.26920	.96308	.28597	.95824	23
38	.23571	.97182	.25263	.96756	.26948	.96301	.28625	.95816	22
39	.23599	.97176	.25291	.96749	.26976	.96293	.28652	.95807	21
40	.23627	.97169	.25320	.96742	.27004	.96285	.28680	.95799	20
41	.23656	.97162	.25348	.96734	.27032	.96277	.28708	.95791	19
42	.23684	.97155	.25376	.96727	.27060	.96269	.28736	.95782	18
43	.23712	.97148	.25404	.96719	.27088	.96261	.28764	.95774	17
44	.23740	.97141	.25432	.96712	.27116	.96253	.28792	.95766	16
45	.23769	.97134	.25460	.96705	.27144	.96246	.28820	.95757	15
46	.23797	.97127	.25488	.96697	.27172	.96238	.28847	.95749	14
47	.23825	.97120	.25516	.96690	.27200	.96230	.28875	.95740	13
48	.23853	.97113	.25545	.96682	.27228	.96222	.28903	.95732	12
49	.23882	.97106	.25573	.96675	.27256	.96214	.28931	.95724	11
50	.23910	.97100	.25601	.96667	.27284	.96206	.28959	.95715	10
51	.23938	.97093	.25629	.96660	.27312	.96198	.28987	.95707	9
52	.23966	.97086	.25657	.96653	.27340	.96190	.29015	.95698	8
53	.23995	.97079	.25685	.96645	.27368	.96182	.29042	.95690	7
54	.24023	.97072	.25713	.96638	.27396	.96174	.29070	.95681	6
55	.24051	.97065	.25741	.96630	.27424	.96166	.29098	.95673	5
56	.24079	.97058	.25769	.96623	.27452	.96158	.29126	.95664	4
57	.24108	.97051	.25798	.96615	.27480	.96150	.29154	.95656	3
58	.24136	.97044	.25826	.96608	.27508	.96142	.29182	.95647	2
59	.24164	.97037	.25854	.96600	.27536	.96134	.29209	.95639	1
60	.24192	.97030	.25882	.96593	.27564	.96126	.29237	.95630	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	76°		75°		74°		73°		

′	17° Sine	17° Cosine	18° Sine	18° Cosine	19° Sine	19° Cosine	20° Sine	20° Cosine	′
0	.29237	.95630	.30902	.95106	.32557	.94552	.34202	.93969	60
1	.29265	.95622	.30929	.95097	.32584	.94542	.34229	.93959	59
2	.29293	.95613	.30957	.95088	.32612	.94533	.34257	.93949	58
3	.29321	.95605	.30985	.95079	.32639	.94523	.34284	.93939	57
4	.29348	.95596	.31012	.95070	.32667	.94514	.34311	.93929	56
5	.29376	.95588	.31040	.95061	.32694	.94504	.34339	.93919	55
6	.29404	.95579	.31068	.95052	.32722	.94495	.34366	.93909	54
7	.29432	.95571	.31095	.95043	.32749	.94485	.34393	.93899	53
8	.29460	.95562	.31123	.95033	.32777	.94476	.34421	.93889	52
9	.29487	.95554	.31151	.95024	.32804	.94466	.34448	.93879	51
10	.29515	.95545	.31178	.95015	.32832	.94457	.34475	.93869	50
11	.29543	.95536	.31206	.95006	.32859	.94447	.34503	.93859	49
12	.29571	.95528	.31233	.94997	.32887	.94438	.34530	.93849	48
13	.29599	.95519	.31261	.94988	.32914	.94428	.34557	.93839	47
14	.29626	.95511	.31289	.94979	.32942	.94418	.34584	.93829	46
15	.29654	.95502	.31316	.94970	.32969	.94409	.34612	.93819	45
16	.29682	.95493	.31344	.94961	.32997	.94399	.34639	.93809	44
17	.29710	.95485	.31372	.94952	.33024	.94390	.34666	.93799	43
18	.29737	.95476	.31399	.94943	.33051	.94380	.34694	.93789	42
19	.29765	.95467	.31427	.94933	.33079	.94370	.34721	.93779	41
20	.29793	.95459	.31454	.94924	.33106	.94361	.34748	.93769	40
21	.29821	.95450	.31482	.94915	.33134	.94351	.34775	.93759	39
22	.29849	.95441	.31510	.94906	.33161	.94342	.34803	.93748	38
23	.29876	.95433	.31537	.94897	.33189	.94332	.34830	.93738	37
24	.29904	.95424	.31565	.94888	.33216	.94322	.34857	.93728	36
25	.29932	.95415	.31593	.94878	.33244	.94313	.34884	.93718	35
26	.29960	.95407	.31620	.94869	.33271	.94303	.34912	.93708	34
27	.29987	.95398	.31648	.94860	.33298	.94293	.34939	.93698	33
28	.30015	.95389	.31675	.94851	.33326	.94284	.34966	.93688	32
29	.30043	.95380	.31703	.94842	.33353	.94274	.34993	.93677	31
30	.30071	.95372	.31730	.94832	.33381	.94264	.35021	.93667	30
31	.30098	.95363	.31758	.94823	.33408	.94254	.35048	.93657	29
32	.30126	.95354	.31786	.94814	.33436	.94245	.35075	.93647	28
33	.30154	.95345	.31813	.94805	.33463	.94235	.35102	.93637	27
34	.30182	.95337	.31841	.94795	.33490	.94225	.35130	.93626	26
35	.30209	.95328	.31868	.94786	.33518	.94215	.35157	.93616	25
36	.30237	.95319	.31896	.94777	.33545	.94206	.35184	.93606	24
37	.30265	.95310	.31923	.94768	.33573	.94196	.35211	.93596	23
38	.30292	.95301	.31951	.94758	.33600	.94186	.35239	.93585	22
39	.30320	.95293	.31979	.94749	.33627	.94176	.35266	.93575	21
40	.30348	.95284	.32006	.94740	.33655	.94167	.35293	.93565	20
41	.30376	.95275	.32034	.94730	.33682	.94157	.35320	.93555	19
42	.30403	.95266	.32061	.94721	.33710	.94147	.35347	.93544	18
43	.30431	.95257	.32089	.94712	.33737	.94137	.35375	.93534	17
44	.30459	.95248	.32116	.94702	.33764	.94127	.35402	.93524	16
45	.30486	.95240	.32144	.94693	.33792	.94118	.35429	.93514	15
46	.30514	.95231	.32171	.94684	.33819	.94108	.35456	.93503	14
47	.30542	.95222	.32199	.94674	.33846	.94098	.35484	.93493	13
48	.30570	.95213	.32227	.94665	.33874	.94088	.35511	.93483	12
49	.30597	.95204	.32254	.94656	.33901	.94078	.35538	.93472	11
50	.30625	.95195	.32282	.94646	.33929	.94068	.35565	.93462	10
51	.30653	.95186	.32309	.94637	.33956	.94058	.35592	.93452	9
52	.30680	.95177	.32337	.94627	.33983	.94049	.35619	.93441	8
53	.30708	.95168	.32364	.94618	.34011	.94039	.35647	.93431	7
54	.30736	.95159	.32392	.94609	.34038	.94029	.35674	.93420	6
55	.30763	.95150	.32419	.94599	.34065	.94019	.35701	.93410	5
56	.30791	.95142	.32447	.94590	.34093	.94009	.35728	.93400	4
57	.30819	.95133	.32474	.94580	.34120	.93999	.35755	.93389	3
58	.30846	.95124	.32502	.94571	.34147	.93989	.35782	.93379	2
59	.30874	.95115	.32529	.94561	.34175	.93979	.35810	.93368	1
60	.30902	.95106	.32557	.94552	.34202	.93969	.35837	.93358	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	72°		71°		70°		69°		

′	21° Sine	21° Cosine	22° Sine	22° Cosine	23° Sine	23° Cosine	24° Sine	24° Cosine	′
0	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	60
1	.35864	.93348	.37488	.92707	.39100	.92039	.40700	.91343	59
2	.35891	.93337	.37515	.92697	.39127	.92028	.40727	.91331	58
3	.35918	.93327	.37542	.92686	.39153	.92016	.40753	.91319	57
4	.35945	.93316	.37569	.92675	.39180	.92005	.40780	.91307	56
5	.35973	.93306	.37595	.92664	.39207	.91994	.40806	.91295	55
6	.36000	.93295	.37622	.92653	.39234	.91982	.40833	.91283	54
7	.36027	.93285	.37649	.92642	.39260	.91971	.40860	.91272	53
8	.36054	.93274	.37676	.92631	.39287	.91959	.40886	.91260	52
9	.36081	.93264	.37703	.92620	.39314	.91948	.40913	.91248	51
10	.36108	.93253	.37730	.92609	.39341	.91936	.40939	.91236	50
11	.36135	.93243	.37757	.92598	.39367	.91925	.40966	.91224	49
12	.36162	.93232	.37784	.92587	.39394	.91914	.40992	.91212	48
13	.36190	.93222	.37811	.92576	.39421	.91902	.41019	.91200	47
14	.36217	.93211	.37838	.92565	.39448	.91891	.41045	.91188	46
15	.36244	.93201	.37865	.92554	.39474	.91879	.41072	.91176	45
16	.36271	.93190	.37892	.92543	.39501	.91868	.41098	.91164	44
17	.36298	.93180	.37919	.92532	.39528	.91856	.41125	.91152	43
18	.36325	.93169	.37946	.92521	.39555	.91845	.41151	.91140	42
19	.36352	.93159	.37973	.92510	.39581	.91833	.41178	.91128	41
20	.36379	.93148	.37999	.92499	.39608	.91822	.41204	.91116	40
21	.36406	.93137	.38026	.92488	.39635	.91810	.41231	.91104	39
22	.36434	.93127	.38053	.92477	.39661	.91799	.41257	.91092	38
23	.36461	.93116	.38080	.92466	.39688	.91787	.41284	.91080	37
24	.36488	.93106	.38107	.92455	.39715	.91775	.41310	.91068	36
25	.36515	.93095	.38134	.92444	.39741	.91764	.41337	.91056	35
26	.36542	.93084	.38161	.92432	.39768	.91752	.41363	.91044	34
27	.36569	.93074	.38188	.92421	.39795	.91741	.41390	.91032	33
28	.36596	.93063	.38215	.92410	.39822	.91729	.41416	.91020	32
29	.36623	.93052	.38241	.92399	.39848	.91718	.41443	.91008	31
30	.36650	.93042	.38268	.92388	.39875	.91706	.41469	.90996	30
31	.36677	.93031	.38295	.92377	.39902	.91694	.41496	.90984	29
32	.36704	.93020	.38322	.92366	.39928	.91683	.41522	.90972	28
33	.36731	.93010	.38349	.92355	.39955	.91671	.41549	.90960	27
34	.36758	.92999	.38376	.92343	.39982	.91660	.41575	.90948	26
35	.36785	.92988	.38403	.92332	.40008	.91648	.41602	.90936	25
36	.36812	.92978	.38430	.92321	.40035	.91636	.41628	.90924	24
37	.36839	.92967	.38456	.92310	.40062	.91625	.41655	.90911	23
38	.36867	.92956	.38483	.92299	.40088	.91613	.41681	.90899	22
39	.36894	.92945	.38510	.92287	.40115	.91601	.41707	.90887	21
40	.36921	.92935	.38537	.92276	.40141	.91590	.41734	.90875	20
41	.36948	.92924	.38564	.92265	.40168	.91578	.41760	.90863	19
42	.36975	.92913	.38591	.92254	.40195	.91566	.41787	.90851	18
43	.37002	.92902	.38617	.92243	.40221	.91555	.41813	.90839	17
44	.37029	.92892	.38644	.92231	.40248	.91543	.41840	.90826	16
45	.37056	.92881	.38671	.92220	.40275	.91531	.41866	.90814	15
46	.37083	.92870	.38698	.92209	.40301	.91519	.41892	.90802	14
47	.37110	.92859	.38725	.92198	.40328	.91508	.41919	.90790	13
48	.37137	.92849	.38752	.92186	.40355	.91496	.41945	.90778	12
49	.37164	.92838	.38778	.92175	.40381	.91484	.41972	.90766	11
50	.37191	.92827	.38805	.92164	.40408	.91472	.41998	.90753	10
51	.37218	.92816	.38832	.92152	.40434	.91461	.42024	.90741	9
52	.37245	.92805	.38859	.92141	.40461	.91449	.42051	.90729	8
53	.37272	.92794	.38886	.92130	.40488	.91437	.42077	.90717	7
54	.37299	.92784	.38912	.92119	.40514	.91425	.42104	.90704	6
55	.37326	.92773	.38939	.92107	.40541	.91414	.42130	.90692	5
56	.37353	.92762	.38966	.92096	.40567	.91402	.42156	.90680	4
57	.37380	.92751	.38993	.92085	.40594	.91390	.42183	.90668	3
58	.37407	.92740	.39020	.92073	.40621	.91378	.42209	.90655	2
59	.37434	.92729	.39046	.92062	.40647	.91366	.42235	.90643	1
60	.37461	.92718	.39073	.92050	.40674	.91355	.42262	.90631	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	68°		67°		66°		65°		

′	25° Sine	25° Cosine	26° Sine	26° Cosine	27° Sine	27° Cosine	28° Sine	28° Cosine	′
0	.42262	.90631	.43837	.89879	.45399	.89101	.46947	.88295	60
1	.42288	.90618	.43863	.89867	.45425	.89087	.46973	.88281	59
2	.42315	.90606	.43889	.89854	.45451	.89074	.46999	.88267	58
3	.42341	.90594	.43916	.89841	.45477	.89061	.47024	.88254	57
4	.42367	.90582	.43942	.89828	.45503	.89048	.47050	.88240	56
5	.42394	.90569	.43968	.89816	.45529	.89035	.47076	.88226	55
6	.42420	.90557	.43994	.89803	.45554	.89021	.47101	.88213	54
7	.42446	.90545	.44020	.89790	.45580	.89008	.47127	.88199	53
8	.42473	.90532	.44046	.89777	.45606	.88995	.47153	.88185	52
9	.42499	.90520	.44072	.89764	.45632	.88981	.47178	.88172	51
10	.42525	.90507	.44098	.89752	.45658	.88968	.47204	.88158	50
11	.42552	.90495	.44124	.89739	.45684	.88955	.47229	.88144	49
12	.42578	.90483	.44151	.89726	.45710	.88942	.47255	.88130	48
13	.42604	.90470	.44177	.89713	.45736	.88928	.47281	.88117	47
14	.42631	.90458	.44203	.89700	.45762	.88915	.47306	.88103	46
15	.42657	.90446	.44229	.89687	.45787	.88902	.47332	.88089	45
16	.42683	.90433	.44255	.89674	.45813	.88888	.47358	.88075	44
17	.42709	.90421	.44281	.89662	.45839	.88875	.47383	.88062	43
18	.42736	.90408	.44307	.89649	.45865	.88862	.47409	.88048	42
19	.42762	.90396	.44333	.89636	.45891	.88848	.47434	.88034	41
20	.42788	.90383	.44359	.89623	.45917	.88835	.47460	.88020	40
21	.42815	.90371	.44385	.89610	.45942	.88822	.47486	.88006	39
22	.42841	.90358	.44411	.89597	.45968	.88808	.47511	.87993	38
23	.42867	.90346	.44437	.89584	.45994	.88795	.47537	.87979	37
24	.42894	.90334	.44464	.89571	.46020	.88782	.47562	.87965	36
25	.42920	.90321	.44490	.89558	.46046	.88768	.47588	.87951	35
26	.42946	.90309	.44516	.89545	.46072	.88755	.47614	.87937	34
27	.42972	.90296	.44542	.89532	.46097	.88741	.47639	.87923	33
28	.42999	.90284	.44568	.89519	.46123	.88728	.47665	.87909	32
29	.43025	.90271	.44594	.89506	.46149	.88715	.47690	.87896	31
30	.43051	.90259	.44620	.89493	.46175	.88701	.47716	.87882	30
31	.43077	.90246	.44646	.89480	.46201	.88688	.47741	.87868	29
32	.43104	.90233	.44672	.89467	.46226	.88674	.47767	.87854	28
33	.43130	.90221	.44698	.89454	.46252	.88661	.47793	.87840	27
34	.43156	.90208	.44724	.89441	.46278	.88647	.47818	.87826	26
35	.43182	.90196	.44750	.89428	.46304	.88634	.47844	.87812	25
36	.43209	.90183	.44776	.89415	.46330	.88620	.47869	.87798	24
37	.43235	.90171	.44802	.89402	.46355	.88607	.47895	.87784	23
38	.43261	.90158	.44828	.89389	.46381	.88593	.47920	.87770	22
39	.43287	.90146	.44854	.89376	.46407	.88580	.47946	.87756	21
40	.43313	.90133	.44880	.89363	.46433	.88566	.47971	.87743	20
41	.43340	.90120	.44906	.89350	.46458	.88553	.47997	.87729	19
42	.43366	.90108	.44932	.89337	.46484	.88539	.48022	.87715	18
43	.43392	.90095	.44958	.89324	.46510	.88526	.48048	.87701	17
44	.43418	.90082	.44984	.89311	.46536	.88512	.48073	.87687	16
45	.43445	.90070	.45010	.89298	.46561	.88499	.48099	.87673	15
46	.43471	.90057	.45036	.89285	.46587	.88485	.48124	.87659	14
47	.43497	.90045	.45062	.89272	.46613	.88472	.48150	.87645	13
48	.43523	.90032	.45088	.89259	.46639	.88458	.48175	.87631	12
49	.43549	.90019	.45114	.89245	.46664	.88445	.48201	.87617	11
50	.43575	.90007	.45140	.89232	.46690	.88431	.48226	.87603	10
51	.43602	.89994	.45166	.89219	.46716	.88417	.48252	.87589	9
52	.43628	.89981	.45192	.89206	.46742	.88404	.48277	.87575	8
53	.43654	.89968	.45218	.89193	.46767	.88390	.48303	.87561	7
54	.43680	.89956	.45243	.89180	.46793	.88377	.48328	.87546	6
55	.43706	.89943	.45269	.89167	.46819	.88363	.48354	.87532	5
56	.43733	.89930	.45295	.89153	.46844	.88349	.48379	.87518	4
57	.43759	.89918	.45321	.89140	.46870	.88336	.48405	.87504	3
58	.43785	.89905	.45347	.89127	.46896	.88322	.48430	.87490	2
59	.43811	.89892	.45373	.89114	.46921	.88308	.48456	.87476	1
60	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	0
	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	64°		63°		62°		61°		

′	29° Sine	29° Cosine	30° Sine	30° Cosine	31° Sine	31° Cosine	32° Sine	32° Cosine	′
0	.48481	.87462	.50000	.86603	.51504	.85717	.52992	.84805	60
1	.48506	.87448	.50025	.86588	.51529	.85702	.53017	.84789	59
2	.48532	.87434	.50050	.86573	.51554	.85687	.53041	.84774	58
3	.48557	.87420	.50076	.86559	.51579	.85672	.53066	.84759	57
4	.48583	.87406	.50101	.86544	.51604	.85657	.53091	.84743	56
5	.48608	.87391	.50126	.86530	.51628	.85642	.53115	.84728	55
6	.48634	.87377	.50151	.86515	.51653	.85627	.53140	.84712	54
7	.48659	.87363	.50176	.86501	.51678	.85612	.53164	.84697	53
8	.48684	.87349	.50201	.86486	.51703	.85597	.53189	.84681	52
9	.48710	.87335	.50227	.86471	.51728	.85582	.53214	.84666	51
10	.48735	.87321	.50252	.86457	.51753	.85567	.53238	.84650	50
11	.48761	.87306	.50277	.86442	.51778	.85551	.53263	.84635	49
12	.48786	.87292	.50302	.86427	.51803	.85536	.53288	.84619	48
13	.48811	.87278	.50327	.86413	.51828	.85521	.53312	.84604	47
14	.48837	.87264	.50352	.86398	.51852	.85506	.53337	.84588	46
15	.48862	.87250	.50377	.86384	.51877	.85491	.53361	.84573	45
16	.48888	.87235	.50403	.86369	.51902	.85476	.53386	.84557	44
17	.48913	.87221	.50428	.86354	.51927	.85461	.53411	.84542	43
18	.48938	.87207	.50453	.86340	.51952	.85446	.53435	.84526	42
19	.48964	.87193	.50478	.86325	.51977	.85431	.53460	.84511	41
20	.48989	.87178	.50503	.86310	.52002	.85416	.53484	.84495	40
21	.49014	.87164	.50528	.86295	.52026	.85401	.53509	.84480	39
22	.49040	.87150	.50553	.86281	.52051	.85385	.53534	.84464	38
23	.49065	.87136	.50578	.86266	.52076	.85370	.53558	.84448	37
24	.49090	.87121	.50603	.86251	.52101	.85355	.53583	.84433	36
25	.49116	.87107	.50628	.86237	.52126	.85340	.53607	.84417	35
26	.49141	.87093	.50654	.86222	.52151	.85325	.53632	.84402	34
27	.49166	.87079	.50679	.86207	.52175	.85310	.53656	.84386	33
28	.49192	.87064	.50704	.86192	.52200	.85294	.53681	.84370	32
29	.49217	.87050	.50729	.86178	.52225	.85279	.53705	.84355	31
30	.49242	.87036	.50754	.86163	.52250	.85264	.53730	.84339	30
31	.49268	.87021	.50779	.86148	.52275	.85249	.53754	.84324	29
32	.49293	.87007	.50804	.86133	.52299	.85234	.53779	.84308	28
33	.49318	.86993	.50829	.86119	.52324	.85218	.53804	.84292	27
34	.49344	.86978	.50854	.86104	.52349	.85203	.53828	.84277	26
35	.49369	.86964	.50879	.86089	.52374	.85188	.53853	.84261	25
36	.49394	.86949	.50904	.86074	.52399	.85173	.53877	.84245	24
37	.49419	.86935	.50929	.86059	.52423	.85157	.53902	.84230	23
38	.49445	.86921	.50954	.86045	.52448	.85142	.53926	.84214	22
39	.49470	.86906	.50979	.86030	.52473	.85127	.53951	.84198	21
40	.49495	.86892	.51004	.86015	.52498	.85112	.53975	.84182	20
41	.49521	.86878	.51029	.86000	.52522	.85096	.54000	.84167	19
42	.49546	.86863	.51054	.85985	.52547	.85081	.54024	.84151	18
43	.49571	.86849	.51079	.85970	.52572	.85066	.54049	.84135	17
44	.49596	.86834	.51104	.85956	.52597	.85051	.54073	.84120	16
45	.49622	.86820	.51129	.85941	.52621	.85035	.54097	.84104	15
46	.49647	.86805	.51154	.85926	.52646	.85020	.54122	.84088	14
47	.49672	.86791	.51179	.85911	.52671	.85005	.54146	.84072	13
48	.49697	.86777	.51204	.85896	.52696	.84989	.54171	.84057	12
49	.49723	.86762	.51229	.85881	.52720	.84974	.54195	.84041	11
50	.49748	.86748	.51254	.85866	.52745	.84959	.54220	.84025	10
51	.49773	.86733	.51279	.85851	.52770	.84943	.54244	.84009	9
52	.49798	.86719	.51304	.85836	.52794	.84928	.54269	.83994	8
53	.49824	.86704	.51329	.85821	.52819	.84913	.54293	.83978	7
54	.49849	.86690	.51354	.85806	.52844	.84897	.54317	.83962	6
55	.49874	.86675	.51379	.85792	.52869	.84882	.54342	.83946	5
56	.49899	.86661	.51404	.85777	.52893	.84866	.54366	.83930	4
57	.49924	.86646	.51429	.85762	.52918	.84851	.54391	.83915	3
58	.49950	.86632	.51454	.85747	.52943	.84836	.54415	.83899	2
59	.49975	.86617	.51479	.85732	.52967	.84820	.54440	.83883	1
60	.50000	.86603	.51504	.85717	.52992	.84805	.54464	.83867	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	60°		59°		58°		57°		

′	33° Sine	33° Cosine	34° Sine	34° Cosine	35° Sine	35° Cosine	36° Sine	36° Cosine	′
0	.54464	.83867	.55919	.82904	.57358	.81915	.58779	.80902	60
1	.54488	.83851	.55943	.82887	.57381	.81899	.58802	.80885	59
2	.54513	.83835	.55968	.82871	.57405	.81882	.58826	.80867	58
3	.54537	.83819	.55992	.82855	.57429	.81865	.58849	.80850	57
4	.54561	.83804	.56016	.82839	.57453	.81848	.58873	.80833	56
5	.54586	.83788	.56040	.82822	.57477	.81832	.58896	.80816	55
6	.54610	.83772	.56064	.82806	.57501	.81815	.58920	.80799	54
7	.54635	.83756	.56088	.82790	.57524	.81798	.58943	.80782	53
8	.54659	.83740	.56112	.82773	.57548	.81782	.58967	.80765	52
9	.54683	.83724	.56136	.82757	.57572	.81765	.58990	.80748	51
10	.54708	.83708	.56160	.82741	.57596	.81748	.59014	.80730	50
11	.54732	.83692	.56184	.82724	.57619	.81731	.59037	.80713	49
12	.54756	.83676	.56208	.82708	.57643	.81714	.59061	.80696	48
13	.54781	.83660	.56232	.82692	.57667	.81698	.59084	.80679	47
14	.54805	.83645	.56256	.82675	.57691	.81681	.59108	.80662	46
15	.54829	.83629	.56280	.82659	.57715	.81664	.59131	.80644	45
16	.54854	.83613	.56305	.82643	.57738	.81647	.59154	.80627	44
17	.54878	.83597	.56329	.82626	.57762	.81631	.59178	.80610	43
18	.54902	.83581	.56353	.82610	.57786	.81614	.59201	.80593	42
19	.54927	.83565	.56377	.82593	.57810	.81597	.59225	.80576	41
20	.54951	.83549	.56401	.82577	.57833	.81580	.59248	.80558	40
21	.54975	.83533	.56425	.82561	.57857	.81563	.59272	.80541	39
22	.54999	.83517	.56449	.82544	.57881	.81546	.59295	.80524	38
23	.55024	.83501	.56473	.82528	.57904	.81530	.59318	.80507	37
24	.55048	.83485	.56497	.82511	.57928	.81513	.59342	.80489	36
25	.55072	.83469	.56521	.82495	.57952	.81496	.59365	.80472	35
26	.55097	.83453	.56545	.82478	.57976	.81479	.59389	.80455	34
27	.55121	.83437	.56569	.82462	.57999	.81462	.59412	.80438	33
28	.55145	.83421	.56593	.82446	.58023	.81445	.59436	.80420	32
29	.55169	.83405	.56617	.82429	.58047	.81428	.59459	.80403	31
30	.55194	.83389	.56641	.82413	.58070	.81412	.59482	.80386	30
31	.55218	.83373	.56665	.82396	.58094	.81395	.59506	.80368	29
32	.55242	.83356	.56689	.823 0	.58118	.81378	.59529	.80351	28
33	.55266	.83340	.56713	.82363	.58141	.81361	.59552	.80334	27
34	.55291	.83324	.56736	.82347	.58165	.81344	.59576	.80316	26
35	.55315	.83308	.56760	.82330	.58189	.81327	.59599	.80299	25
36	.55339	.83292	.56784	.82314	.58212	.81310	.59622	.80282	24
37	.55363	.83276	.56808	.82297	.58236	.81293	.59646	.80264	23
38	.55388	.83260	.56832	.82281	.58260	.81276	.59669	.80247	22
39	.55412	.83244	.56856	.82264	.58283	.81259	.59693	.80230	21
40	.55436	.83228	.56880	.82248	.58307	.81242	.59716	.80212	20
41	.55460	.83212	.56904	.82231	.58330	.81225	.59739	.80195	19
42	.55484	.83195	.56928	.82214	.58354	.81208	.59763	.80178	18
43	.55509	.83179	.56952	.82198	.58378	.81191	.59786	.80160	17
44	.55533	.83163	.56976	.82181	.58401	.81174	.59809	.80143	16
45	.55557	.83147	.57000	.82165	.58425	.81157	.59832	.80125	15
46	.55581	.83131	.57024	.82148	.58449	.81140	.59856	.80108	14
47	.55605	.83115	.57047	.82132	.58472	.81123	.59879	.80091	13
48	.55630	.83098	.57071	.82115	.58496	.81106	.59902	.80073	12
49	.55654	.83082	.57095	.82098	.58519	.81089	.59926	.80056	11
50	.55678	.83066	.57119	.82082	.58543	.81072	.59949	.80038	10
51	.55702	.83050	.57143	.82065	.58567	.81055	.59972	.80021	9
52	.55726	.83034	.57167	.82048	.58590	.81038	.59995	.80003	8
53	.55750	.83017	.57191	.82032	.58614	.81021	.60019	.79986	7
54	.55775	.83001	.57215	.82015	.58637	.81004	.60042	.79968	6
55	.55799	.82985	.57238	.81999	.58661	.80987	.60065	.79951	5
56	.55823	.82969	.57262	.81982	.58684	.80970	.60089	.79934	4
57	.55847	.82953	.57286	.81965	.58708	.80953	.60112	.79916	3
58	.55871	.82936	.57310	.81949	.58731	.80936	.60135	.79899	2
59	.55895	.82920	.57334	.81932	.58755	.80919	.60158	.79881	1
60	.55919	.82904	.57358	.81915	.58779	.80902	.60182	.79864	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	56°		55°		54°		53°		

′	37° Sine	37° Cosine	38° Sine	38° Cosine	39° Sine	39° Cosine	40° Sine	40° Cosine	′
0	.60182	.79864	.61566	.78801	.62932	.77715	.64279	.76604	60
1	.60205	.79846	.61589	.78783	.62955	.77696	.64301	.76586	59
2	.60228	.79829	.61612	.78765	.62977	.77678	.64323	.76567	58
3	.60251	.79811	.61635	.78747	.63000	.77660	.64346	.76548	57
4	.60274	.79793	.61658	.78729	.63022	.77641	.64368	.76530	56
5	.60298	.79776	.61681	.78711	.63045	.77623	.64390	.76511	55
6	.60321	.79758	.61704	.78694	.63068	.77605	.64412	.76492	54
7	.60344	.79741	.61726	.78676	.63090	.77586	.64435	.76473	53
8	.60367	.79723	.61749	.78658	.63113	.77568	.64457	.76455	52
9	.60390	.79706	.61772	.78640	.63135	.77550	.64479	.76436	51
10	.60414	.79688	.61795	.78622	.63158	.77531	.64501	.76417	50
11	.60437	.79671	.61818	.78604	.63180	.77513	.64524	.76398	49
12	.60460	.79653	.61841	.78586	.63203	.77494	.64546	.76380	48
13	.60483	.79635	.61864	.78568	.63225	.77476	.64568	.76361	47
14	.60506	.79618	.61887	.78550	.63248	.77458	.64590	.76342	46
15	.60529	.79600	.61909	.78532	.63271	.77439	.64612	.76323	45
16	.60553	.79583	.61932	.78514	.63293	.77421	.64635	.76304	44
17	.60576	.79565	.61955	.78496	.63316	.77402	.64657	.76286	43
18	.60599	.79547	.61978	.78478	.63338	.77384	.64679	.76267	42
19	.60622	.79530	.62001	.78460	.63361	.77366	.64701	.76248	41
20	.60645	.79512	.62024	.78442	.63383	.77347	.64723	.76229	40
21	.60668	.79494	.62046	.78424	.63406	.77329	.64746	.76210	39
22	.60691	.79477	.62069	.78405	.63428	.77310	.64768	.76192	38
23	.60714	.79459	.62092	.78387	.63451	.77292	.64790	.76173	37
24	.60738	.79441	.62115	.78369	.63473	.77273	.64812	.76154	36
25	.60761	.79424	.62138	.78351	.63496	.77255	.64834	.76135	35
26	.60784	.79406	.62160	.78333	.63518	.77236	.64856	.76116	34
27	.60807	.79388	.62183	.78315	.63540	.77218	.64878	.76097	33
28	.60830	.79371	.62206	.78297	.63563	.77199	.64901	.76078	32
29	.60853	.79353	.62229	.78279	.63585	.77181	.64923	.76059	31
30	.60876	.79335	.62251	.78261	.63608	.77162	.64945	.76041	30
31	.60899	.79318	.62274	.78243	.63630	.77144	.64967	.76022	29
32	.60922	.79300	.62297	.78225	.63653	.77125	.64989	.76003	28
33	.60945	.79282	.62320	.78206	.63675	.77107	.65011	.75984	27
34	.60968	.79264	.62342	.78188	.63698	.77088	.65033	.75965	26
35	.60991	.79247	.62365	.78170	.63720	.77070	.65055	.75946	25
36	.61015	.79229	.62388	.78152	.63742	.77051	.65077	.75927	24
37	.61038	.79211	.62411	.78134	.63765	.77033	.65100	.75908	23
38	.61061	.79193	.62433	.78116	.63787	.77014	.65122	.75889	22
39	.61084	.79176	.62456	.78098	.63810	.76996	.65144	.75870	21
40	.61107	.79158	.62479	.78079	.63832	.76977	.65166	.75851	20
41	.61130	.79140	.62502	.78061	.63854	.76959	.65188	.75832	19
42	.61153	.79122	.62524	.78043	.63877	.76940	.65210	.75813	18
43	.61176	.79105	.62547	.78025	.63899	.76921	.65232	.75794	17
44	.61199	.79087	.62570	.78007	.63922	.76903	.65254	.75775	16
45	.61222	.79069	.62593	.77988	.63944	.76884	.65276	.75756	15
46	.61245	.79051	.62615	.77970	.63966	.76866	.65298	.75738	14
47	.61268	.79033	.62638	.77952	.63989	.76847	.65320	.75719	13
48	.61291	.79016	.62660	.77934	.64011	.76828	.65342	.75700	12
49	.61314	.78998	.62683	.77916	.64033	.76810	.65364	.75680	11
50	.61337	.78980	.62706	.77897	.64056	.76791	.65386	.75661	10
51	.61360	.78962	.62728	.77879	.64078	.76772	.65408	.75642	9
52	.61383	.78944	.62751	.77861	.64100	.76754	.65430	.75623	8
53	.61406	.78926	.62774	.77843	.64123	.76735	.65452	.75604	7
54	.61429	.78908	.62796	.77824	.64145	.76717	.65474	.75585	6
55	.61451	.78891	.62819	.77806	.64167	.76698	.65496	.75566	5
56	.61474	.78873	.62842	.77788	.64190	.76679	.65518	.75547	4
57	.61497	.78855	.62864	.77769	.64212	.76661	.65540	.75528	3
58	.61520	.78837	.62887	.77751	.64234	.76642	.65562	.75509	2
59	.61543	.78819	.62909	.77733	.64256	.76623	.65584	.75490	1
60	.61566	.78801	.62932	.77715	.64279	.76604	.65606	.75471	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	52°		51°		50°		49°		

′	41° Sine	41° Cosine	42° Sine	42° Cosine	43° Sine	43° Cosine	44° Sine	44° Cosine	′
0	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	60
1	.65628	.75452	.66935	.74295	.68221	.73116	.69487	.71914	59
2	.65650	.75433	.66956	.74276	.68242	.73096	.69508	.71894	58
3	.65672	.75414	.66978	.74256	.68264	.73076	.69529	.71873	57
4	.65694	.75395	.66999	.74237	.68285	.73056	.69549	.71853	56
5	.65716	.75375	.67021	.74217	.68306	.73036	.69570	.71833	55
6	.65738	.75356	.67043	.74198	.68327	.73016	.69591	.71813	54
7	.65759	.75337	.67064	.74178	.68349	.72996	.69612	.71792	53
8	.65781	.75318	.67086	.74159	.68370	.72976	.69633	.71772	52
9	.65803	.75299	.67107	.74139	.68391	.72957	.69654	.71752	51
10	.65825	.75280	.67129	.74120	.68412	.72937	.69675	.71732	50
11	.65847	.75261	.67151	.74100	.68434	.72917	.69696	.71711	49
12	.65869	.75241	.67172	.74080	.68455	.72897	.69717	.71691	48
13	.65891	.75222	.67194	.74061	.68476	.72877	.69737	.71671	47
14	.65913	.75203	.67215	.74041	.68497	.72857	.69758	.71650	46
15	.65935	.75184	.67237	.74022	.68518	.72837	.69779	.71630	45
16	.65956	.75165	.67258	.74002	.68539	.72817	.69800	.71610	44
17	.65978	.75146	.67280	.73983	.68561	.72797	.69821	.71590	43
18	.66000	.75126	.67301	.73963	.68582	.72777	.69842	.71569	42
19	.66022	.75107	.67323	.73944	.68603	.72757	.69862	.71549	41
20	.66044	.75088	.67344	.73924	.68624	.72737	.69883	.71529	40
21	.66066	.75069	.67366	.73904	.68645	.72717	.69904	.71508	39
22	.66088	.75050	.67387	.73885	.68666	.72697	.69925	.71488	38
23	.66109	.75030	.67409	.73865	.68688	.72677	.69946	.71468	37
24	.66131	.75011	.67430	.73846	.68709	.72657	.69966	.71447	36
25	.66153	.74992	.67452	.73826	.68730	.72637	.69987	.71427	35
26	.66175	.74973	.67473	.73806	.68751	.72617	.70008	.71407	34
27	.66197	.74953	.67495	.73787	.68772	.72597	.70029	.71386	33
28	.66218	.74934	.67516	.73767	.68793	.72577	.70049	.71366	32
29	.66240	.74915	.67538	.73747	.68814	.72557	.70070	.71345	31
30	.66262	.74896	.67559	.73728	.68835	.72537	.70091	.71325	30
31	.66284	.74876	.67580	.73708	.68857	.72517	.70112	.71305	29
32	.66306	.74857	.67602	.73688	.68878	.72497	.70132	.71284	28
33	.66327	.74838	.67623	.73669	.68899	.72477	.70153	.71264	27
34	.66349	.74818	.67645	.73649	.68920	.72457	.70174	.71243	26
35	.66371	.74799	.67666	.73629	.68941	.72437	.70195	.71223	25
36	.66393	.74780	.67688	.73610	.68962	.72417	.70215	.71203	24
37	.66414	.74760	.67709	.73590	.68983	.72397	.70236	.71182	23
38	.66436	.74741	.67730	.73570	.69004	.72377	.70257	.71162	22
39	.66458	.74722	.67752	.73551	.69025	.72357	.70277	.71141	21
40	.66480	.74703	.67773	.73531	.69046	.72337	.70298	.71121	20
41	.66501	.74683	.67795	.73511	.69067	.72317	.70319	.71100	19
42	.66523	.74664	.67816	.73491	.69088	.72297	.70339	.71080	18
43	.66545	.74644	.67837	.73472	.69109	.72277	.70360	.71059	17
44	.66566	.74625	.67859	.73452	.69130	.72257	.70381	.71039	16
45	.66588	.74606	.67880	.73432	.69151	.72236	.70401	.71019	15
46	.66610	.74586	.67901	.73413	.69172	.72216	.70422	.70998	14
47	.66632	.74567	.67923	.73393	.69193	.72196	.70443	.70978	13
48	.66653	.74548	.67944	.73373	.69214	.72176	.70463	.70957	12
49	.66675	.74528	.67965	.73353	.69235	.72156	.70484	.70937	11
50	.66697	.74509	.67987	.73333	.69256	.72136	.70505	.70916	10
51	.66718	.74489	.68008	.73314	.69277	.72116	.70525	.70896	9
52	.66740	.74470	.68029	.73294	.69298	.72095	.70546	.70875	8
53	.66762	.74451	.68051	.73274	.69319	.72075	.70567	.70855	7
54	.66783	.74431	.68072	.73254	.69340	.72055	.70587	.70834	6
55	.66805	.74412	.68093	.73234	.69361	.72035	.70608	.70813	5
56	.66827	.74392	.68115	.73215	.69382	.72015	.70628	.70793	4
57	.66848	.74373	.68136	.73195	.69403	.71995	.70649	.70772	3
58	.66870	.74353	.68157	.73175	.69424	.71974	.70670	.70752	2
59	.66891	.74334	.68179	.73155	.69445	.71954	.70690	.70731	1
60	.66913	.74314	.68200	.73135	.69466	.71934	.70711	.70711	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	48°		47°		46°		45°		

′	0° Sec.	0° Co-sec.	1° Sec.	1° Co-sec.	2° Sec.	2° Co-sec.	3° Sec.	3° Co-sec.	′
0	1	Infinite.	1.0001	57.299	1.0006	28.654	1.0014	19.107	60
1	1	3437.70	1.0001	56.359	1.0006	28.417	1.0014	19.002	59
2	1	1718.90	1.0002	55.450	1.0006	28.184	1.0014	18.897	58
3	1	1145.90	1.0002	54.570	1.0006	27.955	1.0014	18.794	57
4	1	859.44	1.0002	53.718	1.0006	27.730	1.0014	18.692	56
5	1	687.55	1.0002	52.891	1.0007	27.508	1.0014	18.591	55
6	1	572.96	1.0002	52.090	1.0007	27.290	1.0015	18.491	54
7	1	491.11	1.0002	51.313	1.0007	27.075	1.0015	18.393	53
8	1	429.72	1.0002	50.558	1.0007	26.864	1.0015	18.295	52
9	1	381.97	1.0002	49.826	1.0007	26.655	1.0015	18.198	51
10	1	343.77	1.0002	49.114	1.0007	26.450	1.0015	18.103	50
11	1	312.52	1.0002	48.422	1.0007	26.249	1.0015	18.008	49
12	1	286.48	1.0002	47.750	1.0007	26.050	1.0016	17.914	48
13	1	264.44	1.0002	47.096	1.0007	25.854	1.0016	17.821	47
14	1	245.55	1.0002	46.460	1.0008	25.661	1.0016	17.730	46
15	1	229.18	1.0002	45.840	1.0008	25.471	1.0016	17.639	45
16	1	214.86	1.0002	45.237	1.0008	25.284	1.0016	17.549	44
17	1	202.22	1.0002	44.650	1.0008	25.100	1.0016	17.460	43
18	1	190.99	1.0002	44.077	1.0008	24.918	1.0017	17.372	42
19	1	180.73	1.0003	43.520	1.0008	24.739	1.0017	17.285	41
20	1	171.89	1.0003	42.976	1.0008	24.562	1.0017	17.198	40
21	1	163.70	1.0003	42.445	1.0008	24.358	1.0017	17.113	39
22	1	156.26	1.0003	41.928	1.0008	24.216	1.0017	17.028	38
23	1	149.47	1.0003	41.423	1.0009	24.047	1.0017	16.944	37
24	1	143.24	1.0003	40.930	1.0009	23.880	1.0018	16.861	36
25	1	137.51	1.0003	40.448	1.0009	23.716	1.0018	16.779	35
26	1	132.22	1.0003	39.978	1.0009	23.553	1.0018	16.698	34
27	1	127.32	1.0003	39.518	1.0009	23.393	1.0018	16.617	33
28	1	122.78	1.0003	39.069	1.0009	23.235	1.0018	16.538	32
29	1	118.54	1.0003	38.631	1.0009	23.079	1.0018	16.459	31
30	1	114.59	1.0003	38.201	1.0009	22.925	1.0019	16.380	30
31	1	110.90	1.0003	37.782	1.0010	22.774	1.0019	16.303	29
32	1	107.43	1.0003	37.371	1.0010	22.624	1.0019	16.226	28
33	1	104.17	1.0004	36.969	1.0010	22.476	1.0019	16.150	27
34	1	101.11	1.0004	36.576	1.0010	22.330	1.0019	16.075	26
35	1	98.223	1.0004	36.191	1.0010	22.186	1.0019	16.000	25
36	1	95.405	1.0004	35.814	1.0010	22.044	1.0020	15.926	24
37	1	92.914	1.0004	35.445	1.0010	21.904	1.0020	15.853	23
38	1.0001	92.469	1.0004	35.084	1.0010	21.765	1.0020	15.780	22
39	1.0001	88.149	1.0004	34.729	1.0011	21.629	1.0020	15.708	21
40	1.0001	85.946	1.0004	34.382	1.0011	21.494	1.0020	15.637	20
41	1.0001	83.849	1.0004	34.042	1.0011	21.360	1.0021	15.566	19
42	1.0001	81.853	1.0004	33.708	1.0011	21.228	1.0021	15.496	18
43	1.0001	79.950	1.0004	33.381	1.0011	21.098	1.0021	15.427	17
44	1.0001	78.133	1.0004	33.060	1.0011	20.970	1.0021	15.358	16
45	1.0001	76.396	1.0005	32.745	1.0011	20.843	1.0021	15.290	15
46	1.0001	74.736	1.0005	32.437	1.0012	20.717	1.0022	15.222	14
47	1.0001	73.146	1.0005	32.134	1.0012	20.593	1.0022	15.155	13
48	1.0001	71.622	1.0005	31.836	1.0012	20.471	1.0022	15.089	12
49	1.0001	71.160	1.0005	31.544	1.0012	20.350	1.0022	15.023	11
50	1.0001	68.757	1.0005	31.257	1.0012	20.230	1.0022	14.958	10
51	1.0001	67.409	1.0005	30.976	1.0012	20.112	1.0023	14.893	9
52	1.0001	66.113	1.0005	30.699	1.0012	19.995	1.0023	14.829	8
53	1.0001	64.866	1.0005	30.428	1.0013	19.880	1.0023	14.765	7
54	1.0001	63.664	1.0005	30.161	1.0013	19.766	1.0023	14.702	6
55	1.0001	62.507	1.0005	29.899	1.0013	19.653	1.0023	14.640	5
56	1.0001	61.391	1.0006	29.641	1.0013	19.541	1.0024	14.578	4
57	1.0001	61.314	1.0006	29.388	1.0013	19.431	1.0024	14.517	3
58	1.0001	59.274	1.0006	29.139	1.0013	19.322	1.0024	14.456	2
59	1.0001	58.270	1.0006	28.894	1.0013	19.214	1.0024	14.395	1
60	1.0001	57.299	1.0006	28.654	1.0014	19.107	1.0024	14.335	0
′	89° Co-sec.	89° Sec.	88° Co-sec.	88° Sec.	87° Co-sec.	87° Sec.	86° Co-sec.	86° Sec.	′

′	4° Sec.	4° Co-sec.	5° Sec.	5° Co-sec.	6° Sec.	6° Co-sec	7° Sec.	7° Co-sec.	′
0	1.0024	14.335	1.0038	11.474	1.0055	9.5668	1.0075	8.2055	60
1	1.0025	14.276	1.0038	11.436	1.0055	9.5404	1.0075	8.1861	59
2	1.0025	14.217	1.0039	11.398	1.0056	9.5141	1.0076	8.1668	58
3	1.0025	14.159	1.0039	11.360	1.0056	9.4880	1.0076	8.1476	57
4	1.0025	14.101	1.0039	11.323	1.0056	9.4620	1.0076	8.1285	56
5	1.0025	14.043	1.0039	11.286	1.0057	9.4362	1.0077	8.1094	55
6	1.0026	13.986	1.0040	11.249	1.0057	9.4105	1.0077	8.0905	54
7	1.0026	13.930	1.0040	11.213	1.0057	9.3850	1.0078	8.0717	53
8	1.0026	13.874	1.0040	11.176	1.0057	9.3596	1.0078	8.0529	52
9	1.0026	13.818	1.0040	11.140	1.0058	9.3343	1.0078	8.0342	51
10	1.0026	13.763	1.0041	11.104	1.0058	9.3092	1.0079	8.0156	50
11	1.0027	13.708	1.0041	11.069	1.0058	9.2842	1.0079	7.9971	49
12	1.0027	13.654	1.0041	11.033	1.0059	9.2593	1.0079	7.9787	48
13	1.0027	13.600	1.0041	10.988	1.0059	9.2346	1.0080	7.9604	47
14	1.0027	13.547	1.0042	10.963	1.0059	9.2100	1.0080	7.9421	46
15	1.0027	13.494	1.0042	10.929	1.0060	9.1855	1.0080	7.9240	45
16	1.0028	13.441	1.0042	10.894	1.0060	9.1612	1.0081	7.9059	44
17	1.0028	13.389	1.0043	10.860	1.0060	9.1370	1.0081	7.8879	43
18	1.0028	13.337	1.0043	10.826	1.0061	9.1129	1.0082	7.8700	42
19	1.0028	13.286	1.0043	10.792	1.0061	9.0890	1.0082	7.8522	41
20	1.0029	13.235	1.0043	10.758	1.0061	9.0651	1.0082	7.8344	40
21	1.0029	13.184	1.0044	10.725	1.0062	9.0414	1.0083	7.8168	39
22	1.0029	13.134	1.0044	10.692	1.0062	9.0179	1.0083	7.7992	38
23	1.0029	13.084	1.0044	10.659	1.0062	8.9944	1.0084	7.7817	37
24	1.0029	13.034	1.0044	10.626	1.0063	8.9711	1.0084	7.7642	36
25	1.0030	12.985	1.0045	10.593	1.0063	8.9479	1.0084	7.7469	35
26	1.0030	12.937	1.0045	10.561	1.0063	8.9248	1.0085	7.7296	34
27	1.0030	12.888	1.0045	10.529	1.0064	8.9018	1.0085	7.7124	33
28	1.0030	12.840	1.0046	10.497	1.0064	8.8790	1.0085	7.6953	32
29	1.0031	12.793	1.0046	10.465	1.0064	8.8563	1.0086	7.6783	31
30	1.0031	12.745	1.0046	10.433	1.0065	8.8337	1.0086	7.6613	30
31	1.0031	12.698	1.0046	10.402	1.0065	8.8112	1.0087	7.6444	29
32	1.0031	12.652	1.0047	10.371	1.0065	8.7888	1.0087	7.6276	28
33	1.0032	12.606	1.0047	10.340	1.0066	8.7665	1.0087	7.6108	27
34	1.0032	12.560	1.0047	10.309	1.0066	8.7444	1.0088	7.5942	26
35	1.0032	12.514	1.0048	10.278	1.0066	8.7223	1.0088	7.5776	25
36	1.0032	12.469	1.0048	10.248	1.0067	8.7004	1.0089	7.5611	24
37	1.0032	12.424	1.0048	10.217	1.0067	8.6786	1.0089	7.5446	23
38	1.0033	12.379	1.0048	10.187	1.0067	8.6569	1.0089	7.5282	22
39	1.0033	12.335	1.0049	10.157	1.0068	8.6353	1.0090	7.5119	21
40	1.0033	12.291	1.0049	10.127	1.0068	8.6138	1.0090	7.4957	20
41	1.0033	12.248	1.0049	10.098	1.0068	8.5924	1.0090	7.4795	19
42	1.0034	12.204	1.0050	10.068	1.0069	8.5711	1.0091	7.4634	18
43	1.0034	12.161	1.0050	10.039	1.0069	8.5499	1.0091	7.4474	17
44	1.0034	12.118	1.0050	10.010	1.0069	8.5289	1.0092	7.4315	16
45	1.0034	12.076	1.0050	9.9812	1.0070	8.5079	1.0092	7.4156	15
46	1.0035	12.034	1.0051	9.9525	1.0070	8.4871	1.0092	7.3998	14
47	1.0035	11.992	1.0051	9.9239	1.0070	8.4663	1.0093	7.3840	13
48	1.0035	11.950	1.0051	9.8955	1.0071	8.4457	1.0093	7.3683	12
49	1.0035	11.909	1.0052	9.8672	1.0071	8.4251	1.0094	7.3527	11
50	1.0036	11.868	1.0052	9.8391	1.0071	8.4046	1.0094	7.3372	10
51	1.0036	11.828	1.0052	9.8112	1.0072	8.3843	1.0094	7.3217	9
52	1.0036	11.787	1.0053	9.7834	1.0072	8.3640	1.0095	7.3063	8
53	1.0036	11.747	1.0053	9.7558	1.0073	8.3439	1.0095	7.2909	7
54	1.0037	11.707	1.0053	9.7283	1.0073	8.3238	1.0096	7.2757	6
55	1.0037	11.668	1.0053	9.7010	1.0073	8.3039	1.0096	7.2604	5
56	1.0037	11.628	1.0054	9.6739	1.0074	8.2840	1.0097	7.2453	4
57	1.0037	11.589	1.0054	9.6469	1.0074	8.2642	1.0097	7.2302	3
58	1.0038	11.550	1.0054	9.6200	1.0074	8.2446	1.0097	7.2152	2
59	1.0038	11.512	1.0055	9.5933	1.0075	8.2250	1.0098	7.2002	1
60	1.0038	11.474	1.0055	9.5668	1.0075	8.2055	1.0098	7.1853	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	85°		84°		83°		82°		

′	8° Sec.	8° Co-sec.	9° Sec.	9° Co-sec.	10° Sec.	10° Co-sec.	11° Sec.	11° Co-sec.	′
0	1.0098	7.1853	1.0125	6.3924	1.0154	5.7588	1.0187	5.2408	60
1	1.0099	7.1704	1.0125	6.3807	1.0155	5.7493	1.0188	5.2330	59
2	1.0099	7.1557	1.0125	6.3690	1.0155	5.7398	1.0188	5.2252	58
3	1.0099	7.1409	1.0126	6.3574	1.0156	5.7304	1.0189	5.2174	57
4	1.0100	7.1263	1.0126	6.3458	1.0156	5.7210	1.0189	5.2097	56
5	1.0100	7.1117	1.0127	6.3343	1.0157	5.7117	1.0190	5.2019	55
6	1.0101	7.0972	1.0127	6.3228	1.0157	5.7023	1.0191	5.1942	54
7	1.0101	7.0827	1.0128	6.3113	1.0158	5.6930	1.0191	5.1865	53
8	1.0102	7.0683	1.0128	6.2999	1.0158	5.6838	1.0192	5.1788	52
9	1.0102	7.0539	1.0129	6.2885	1.0159	5.6745	1.0192	5.1712	51
10	1.0102	7.0396	1.0129	6.2772	1.0159	5.6653	1.0193	5.1636	50
11	1.0103	7.0254	1.0130	6.2659	1.0160	5.6561	1.0193	5.1560	49
12	1.0103	7.0112	1.0130	6.2546	1.0160	5.6470	1.0194	5.1484	48
13	1.0104	6.9971	1.0131	6.2434	1.0161	5.6379	1.0195	5.1409	47
14	1.0104	6.9830	1.0131	6.2322	1.0162	5.6288	1.0195	5.1333	46
15	1.0104	6.9690	1.0132	6.2211	1.0162	5.6197	1.0196	5.1258	45
16	1.0105	6.9550	1.0132	6.2100	1.0163	5.6107	1.0196	5.1183	44
17	1.0105	6.9411	1.0133	6.1990	1.0163	5.6017	1.0197	5.1109	43
18	1.0106	6.9273	1.0133	6.1880	1.0164	5.5928	1.0198	5.1034	42
19	1.0106	6.9135	1.0134	6.1770	1.0164	5.5838	1.0198	5.0960	41
20	1.0107	6.8998	1.0134	6.1661	1.0165	5.5749	1.0199	5.0886	40
21	1.0107	6.8861	1.0135	6.1552	1.0165	5.5660	1.0199	5.0812	39
22	1.0107	6.8725	1.0135	6.1443	1.0166	5.5572	1.0200	5.0739	38
23	1.0108	6.8589	1.0136	6.1335	1.0166	5.5484	1.0201	5.0666	37
24	1.0108	6.8454	1.0136	6.1227	1.0167	5.5396	1.0201	5.0593	36
25	1.0109	6.8320	1.0136	6.1120	1.0167	5.5308	1.0202	5.0520	35
26	1.0109	6.8185	1.0137	6.1013	1.0168	5.5221	1.0202	5.0447	34
27	1.0110	6.8052	1.0137	6.0906	1.0169	5.5134	1.0203	5.0375	33
28	1.0110	6.7919	1.0138	6.0800	1.0169	5.5047	1.0204	5.0302	32
29	1.0111	6.7787	1.0138	6.0694	1.0170	5.4960	1.0204	5.0230	31
30	1.0111	6.7655	1.0139	6.0588	1.0170	5.4874	1.0205	5.0158	30
31	1.0111	6.7523	1.0139	6.0483	1.0171	5.4788	1.0205	5.0087	29
32	1.0112	6.7392	1.0140	6.0379	1.0171	5.4702	1.0206	5.0015	28
33	1.0112	6.7262	1.0140	6.0274	1.0172	5.4617	1.0207	4.9944	27
34	1.0113	6.7132	1.0141	6.0170	1.0172	5.4532	1.0207	4.9873	26
35	1.0113	6.7003	1.0141	6.0066	1.0173	5.4447	1.0208	4.9802	25
36	1.0114	6.6874	1.0142	5.9963	1.0174	5.4362	1.0208	4.9732	24
37	1.0114	6.6745	1.0142	5.9860	1.0174	5.4278	1.0209	4.9661	23
38	1.0115	6.6617	1.0143	5.9758	1.0175	5.4194	1.0210	4.9591	22
39	1.0115	6.6490	1.0143	5.9655	1.0175	5.4110	1.0210	4.9521	21
40	1.0115	6.6363	1.0144	5.9554	1.0176	5.4026	1.0211	4.9452	20
41	1.0116	6.6237	1.0144	5.9452	1.0176	5.3943	1.0211	4.9382	19
42	1.0116	6.6111	1.0145	5.9351	1.0177	5.3860	1.0212	4.9313	18
43	1.0117	6.5985	1.0145	5.9250	1.0177	5.3777	1.0213	4.9243	17
44	1.0117	6.5860	1.0146	5.9150	1.0178	5.3695	1.0213	4.9175	16
45	1.0118	6.5736	1.0146	5.9049	1.0179	5.3612	1.0214	4.9106	15
46	1.0118	6.5612	1.0147	5.8950	1.0179	5.3530	1.0215	4.9037	14
47	1.0119	6.5488	1.0147	5.8850	1.0180	5.3449	1.0215	4.8969	13
48	1.0119	6.5365	1.0148	5.8751	1.0180	5.3367	1.0216	4.8901	12
49	1.0119	6.5243	1.0148	5.8652	1.0181	5.3286	1.0216	4.8833	11
50	1.0120	6.5121	1.0149	5.8554	1.0181	5.3205	1.0217	4.8765	10
51	1.0120	6.4999	1.0150	5.8456	1.0182	5.3124	1.0218	4.8697	9
52	1.0121	6.4878	1.0150	5.8358	1.0182	5.3044	1.0218	4.8630	8
53	1.0121	6.4757	1.0151	5.8261	1.0183	5.2963	1.0219	4.8563	7
54	1.0122	6.4637	1.0151	5.8163	1.0184	5.2883	1.0220	4.8496	6
55	1.0122	6.4517	1.0152	5.8067	1.0184	5.2803	1.0220	4.8429	5
56	1.0123	6.4398	1.0152	5.7970	1.0185	5.2724	1.0221	4.8362	4
57	1.0123	6.4279	1.0153	5.7874	1.0185	5.2645	1.0221	4.8296	3
58	1.0124	6.4160	1.0153	5.7778	1.0186	5.2566	1.0222	4.8229	2
59	1.0124	6.4042	1.0154	5.7683	1.0186	5.2487	1.0223	4.8163	1
60	1.0125	6.3924	1.0154	5.7588	1.0187	5.2408	1.0223	4.8097	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	81°		80°		79°		78°		

′	12° Sec.	12° Co-sec.	13° Sec.	13° Co-sec.	14° Sec.	14° Co-sec.	15° Sec.	15° Co-sec.	′
0	1.0223	4.8097	1.0263	4.4454	1.0306	4.1336	1.0353	3.8637	60
1	1.0224	4.8032	1.0264	4.4398	1.0307	4.1287	1.0353	3.8595	59
2	1.0225	4.7966	1.0264	4.4342	1.0308	4.1239	1.0354	3.8553	58
3	1.0225	4.7901	1.0265	4.4287	1.0308	4.1191	1.0355	3.8512	57
4	1.0226	4.7835	1.0266	4.4231	1.0309	4.1144	1.0356	3.8470	56
5	1.0226	4.7770	1.0266	4.4176	1.0310	4.1096	1.0357	3.8428	55
6	1.0227	4.7706	1.0267	4.4121	1.0311	4.1048	1.0358	3.8387	54
7	1.0228	4.7641	1.0268	4.4065	1.0311	4.1001	1.0358	3.8346	53
8	1.0228	4.7576	1.0268	4.4011	1.0312	4.0953	1.0359	3.8304	52
9	1.0229	4.7512	1.0269	4.3956	1.0313	4.0906	1.0360	3.8263	51
10	1.0230	4.7448	1.0270	4.3910	1.0314	4.0859	1.0361	3.8222	50
11	1.0230	4.7384	1.0271	4.3847	1.0314	4.0812	1.0362	3.8181	49
12	1.0231	4.7320	1.0271	4.3792	1.0315	4.0765	1.0362	3.8140	48
13	1.0232	4.7257	1.0272	4.3738	1.0316	4.0718	1.0363	3.8100	47
14	1.0232	4.7193	1.0273	4.3684	1.0317	4.0672	1.0364	3.8059	46
15	1.0233	4.7130	1.0273	4.3630	1.0317	4.0625	1.0365	3.8018	45
16	1.0234	4.7067	1.0274	4.3576	1.0318	4.0579	1.0366	3.7978	44
17	1.0234	4.7004	1.0275	4.3522	1.0319	4.0532	1.0367	3.7937	43
18	1.0235	4.6942	1.0276	4.3469	1.0320	4.0486	1.0367	3.7897	42
19	1.0235	4.6879	1.0276	4.3415	1.0320	4.0440	1.0368	3.7857	41
20	1.0236	4.6817	1.0277	4.3362	1.0321	4.0394	1.0369	3.7816	40
21	1.0237	4.6754	1.0278	4.3309	1.0322	4.0348	1.0370	3.7776	39
22	1.0237	4.6692	1.0278	4.3256	1.0323	4.0302	1.0371	3.7736	38
23	1.0238	4.6631	1.0279	4.3203	1.0323	4.0256	1.0371	3.7697	37
24	1.0239	4.6569	1.0280	4.3150	1.0324	4.0211	1.0372	3.7657	36
25	1.0239	4.6507	1.0280	4.3098	1.0325	4.0165	1.0373	3.7617	35
26	1.0240	4.6446	1.0281	4.3045	1.0326	4.0120	1.0374	3.7577	34
27	1.0241	4.6385	1.0282	4.2993	1.0327	4.0074	1.0375	3.7538	33
28	1.0241	4.6324	1.0283	4.2941	1.0327	4.0029	1.0376	3.7498	32
29	1.0242	4.6263	1.0283	4.2888	1.0328	3.9984	1.0376	3.7459	31
30	1.0243	4.6202	1.0284	4.2836	1.0329	3.9939	1.0377	3.7420	30
31	1.0243	4.6142	1.0285	4.2785	1.0330	3.9894	1.0378	3.7380	29
32	1.0244	4.6081	1.0285	4.2733	1.0330	3.9850	1.0379	3.7341	28
33	1.0245	4.6021	1.0286	4.2681	1.0331	3.9805	1.0380	3.7302	27
34	1.0245	4.5961	1.0287	4.2630	1.0332	3.9760	1.0381	3.7263	26
35	1.0246	4.5901	1.0288	4.2579	1.0333	3.9716	1.0382	3.7224	25
36	1.0247	4.5841	1.0288	4.2527	1.0334	3.9672	1.0382	3.7186	24
37	1.0247	4.5782	1.0289	4.2476	1.0334	3.9627	1.0383	3.7147	23
38	1.0248	4.5722	1.0290	4.2425	1.0335	3.9583	1.0384	3.7108	22
39	1.0249	4.5663	1.0291	4.2375	1.0336	3.9539	1.0385	3.7070	21
40	1.0249	4.5604	1.0291	4.2324	1.0337	3.9495	1.0386	3.7031	20
41	1.0250	4.5545	1.0292	4.2273	1.0338	3.9451	1.0387	3.6993	19
42	1.0251	4.5486	1.0293	4.2223	1.0338	3.9408	1.0387	3.6955	18
43	1.0251	4.5428	1.0293	4.2173	1.0339	3.9364	1.0388	3.6917	17
44	1.0252	4.5369	1.0294	4.2122	1.0340	3.9320	1.0389	3.6878	16
45	1.0253	4.5311	1.0295	4.2072	1.0341	3.9277	1.0390	3.6840	15
46	1.0253	4.5253	1.0296	4.2022	1.0341	3.9234	1.0391	3.6802	14
47	1.0254	4.5195	1.0296	4.1972	1.0342	3.9190	1.0392	3.6765	13
48	1.0255	4.5137	1.0297	4.1923	1.0343	3.9147	1.0393	3.6727	12
49	1.0255	4.5079	1.0298	4.1873	1.0344	3.9104	1.0393	3.6689	11
50	1.0256	4.5021	1.0299	4.1824	1.0345	3.9061	1.0394	3.6651	10
51	1.0257	4.4964	1.0299	4.1774	1.0345	3.9018	1.0395	3.6614	9
52	1.0257	4.4907	1.0300	4.1725	1.0346	3.8976	1.0396	3.6576	8
53	1.0258	4.4850	1.0301	4.1676	1.0347	3.8933	1.0397	3.6539	7
54	1.0259	4.4793	1.0302	4.1627	1.0348	3.8890	1.0398	3.6502	6
55	1.0260	4.4736	1.0302	4.1578	1.0349	3.8848	1.0399	3.6464	5
56	1.0260	4.4679	1.0303	4.1529	1.0349	3.8805	1.0399	3.6427	4
57	1.0261	4.4623	1.0304	4.1481	1.0350	3.8763	1.0400	3.6390	3
58	1.0262	4.4566	1.0305	4.1432	1.0351	3.8721	1.0401	3.6353	2
59	1.0262	4.4510	1.0305	4.1384	1.0352	3.8679	1.0402	3.6316	1
60	1.0263	4.4454	1.0306	4.1336	1.0353	3.8637	1.0403	3.6279	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	77°		76°		75°		74°		

′	16° Sec.	16° Co-sec.	17° Sec.	17° Co-sec.	18° Sec.	18° Co-sec.	19° Sec.	19° Co-sec.	′
0	1.0403	3.6279	1.0457	3.4203	1.0515	3.2361	1.0576	3.0715	60
1	1.0404	3.6243	1.0458	3.4170	1.0516	3.2332	1.0577	3.0690	59
2	1.0405	3.6206	1.0459	3.4138	1.0517	3.2303	1.0578	3.0664	58
3	1.0406	3.6169	1.0460	3.4106	1.0518	3.2274	1.0579	3.0638	57
4	1.0406	3.6133	1.0461	3.4073	1.0519	3.2245	1.0580	3.0612	56
5	1.0407	3.6096	1.0461	3.4041	1.0520	3.2216	1.0581	3.0586	55
6	1.0408	3.6060	1.0462	3.4009	1.0521	3.2188	1.0582	3.0561	54
7	1.0409	3.6024	1.0463	3.3977	1.0522	3.2159	1.0584	3.0535	53
8	1.0410	3.5987	1.0464	3.3945	1.0523	3.2131	1.0585	3.0509	52
9	1.0411	3.5951	1.0465	3.3913	1.0524	3.2102	1.0586	3.0484	51
10	1.0412	3.5915	1.0466	3.3881	1.0525	3.2074	1.0587	3.0458	50
11	1.0413	3.5879	1.0467	3.3849	1.0526	3.2045	1.0588	3.0433	49
12	1.0413	3.5843	1.0468	3.3817	1.0527	3.2017	1.0589	3.0407	48
13	1.0414	3.5807	1.0469	3.3785	1.0528	3.1989	1.0590	3.0382	47
14	1.0415	3.5772	1.0470	3.3754	1.0529	3.1960	1.0591	3.0357	46
15	1.0416	3.5736	1.0471	3.3722	1.0530	3.1932	1.0592	3.0331	45
16	1.0417	3.5700	1.0472	3.3690	1.0531	3.1904	1.0593	3.0306	44
17	1.0418	3.5665	1.0473	3.3659	1.0532	3.1876	1.0594	3.0281	43
18	1.0419	3.5629	1.0474	3.3627	1.0533	3.1848	1.0595	3.0256	42
19	1.0420	3.5594	1.0475	3.3596	1.0534	3.1820	1.0596	3.0231	41
20	1.0420	3.5559	1.0476	3.3565	1.0535	3.1792	1.0598	3.0206	40
21	1.0421	3.5523	1.0477	3.3534	1.0536	3.1764	1.0599	3.0181	39
22	1.0422	3.5488	1.0478	3.3502	1.0537	3.1736	1.0600	3.0156	38
23	1.0423	3.5453	1.0478	3.3471	1.0538	3.1708	1.0601	3.0131	37
24	1.0424	3.5418	1.0479	3.3440	1.0539	3.1681	1.0602	3.0106	36
25	1.0425	3.5383	1.0480	3.3409	1.0540	3.1653	1.0603	3.0081	35
26	1.0426	3.5348	1.0481	3.3378	1.0541	3.1625	1.0604	3.0056	34
27	1.0427	3.5313	1.0482	3.3347	1.0542	3.1598	1.0605	3.0031	33
28	1.0428	3.5279	1.0483	3.3316	1.0543	3.1570	1.0606	3.0007	32
29	1.0428	3.5244	1.0484	3.3286	1.0544	3.1543	1.0607	2.9982	31
30	1.0429	3.5209	1.0485	3.3255	1.0545	3.1515	1.0608	2.9957	30
31	1.0430	3.5175	1.0486	3.3224	1.0546	3.1488	1.0609	2.9933	29
32	1.0431	3.5140	1.0487	3.3194	1.0547	3.1461	1.0611	2.9908	28
33	1.0432	3.5106	1.0488	3.3163	1.0548	3.1433	1.0612	2.9884	27
34	1.0433	3.5072	1.0489	3.3133	1.0549	3.1406	1.0613	2.9859	26
35	1.0434	3.5037	1.0490	3.3102	1.0550	3.1379	1.0614	2.9835	25
36	1.0435	3.5003	1.0491	3.3072	1.0551	3.1352	1.0615	2.9810	24
37	1.0436	3.4969	1.0492	3.3042	1.0552	3.1325	1.0616	2.9786	23
38	1.0437	3.4935	1.0493	3.3011	1.0553	3.1298	1.0617	2.9762	22
39	1.0438	3.4901	1.0494	3.2981	1.0554	3.1271	1.0618	2.9738	21
40	1.0438	3.4867	1.0495	3.2951	1.0555	3.1244	1.0619	2.9713	20
41	1.0439	3.4833	1.0496	3.2921	1.0556	3.1217	1.0620	2.9689	19
42	1.0440	3.4799	1.0497	3.2891	1.0557	3.1190	1.0622	2.9665	18
43	1.0441	3.4766	1.0498	3.2861	1.0558	3.1163	1.0623	2.9641	17
44	1.0442	3.4732	1.0499	3.2831	1.0559	3.1137	1.0624	2.9617	16
45	1.0443	3.4698	1.0500	3.2801	1.0560	3.1110	1.0625	2.9593	15
46	1.0444	3.4665	1.0501	3.2772	1.0561	3.1083	1.0626	2.9569	14
47	1.0445	3.4632	1.0502	3.2742	1.0562	3.1057	1.0627	2.9545	13
48	1.0446	3.4598	1.0503	3.2712	1.0563	3.1030	1.0628	2.9521	12
49	1.0447	3.4565	1.0504	3.2683	1.0565	3.1004	1.0629	2.9497	11
50	1.0448	3.4532	1.0505	3.2653	1.0566	3.0977	1.0630	2.9474	10
51	1.0448	3.4498	1.0506	3.2624	1.0567	3.0951	1.0632	2.9450	9
52	1.0449	3.4465	1.0507	3.2594	1.0568	3.0925	1.0633	2.9426	8
53	1.0450	3.4432	1.0508	3.2565	1.0569	3.0898	1.0634	2.9402	7
54	1.0451	3.4399	1.0509	3.2535	1.0570	3.0872	1.0635	2.9379	6
55	1.0452	3.4366	1.0510	3.2506	1.0571	3.0846	1.0636	2.9355	5
56	1.0453	3.4334	1.0511	3.2477	1.0572	3.0820	1.0637	2.9332	4
57	1.0454	3.4301	1.0512	3.2448	1.0573	3.0793	1.0638	2.9308	3
58	1.0455	3.4268	1.0513	3.2419	1.0574	3.0767	1.0639	2.9285	2
59	1.0456	3.4236	1.0514	3.2390	1.0575	3.0741	1.0641	2.9261	1
60	1.0457	3.4203	1.0515	3.2361	1.0576	3.0715	1.0642	2.9238	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	73°		72°		71°		70°		

′	20° Sec.	20° Co-sec.	21° Sec.	21° Co-sec.	22° Sec.	22° Co-sec.	23° Sec.	23° Co-sec.	′
0	1.0642	2.9238	1.0711	2.7904	1.0785	2.6695	1.0864	2.5593	60
1	1.0643	2.9215	1.0713	2.7883	1.0787	2.6675	1.0865	2.5575	59
2	1.0644	2.9191	1.0714	2.7862	1.0788	2.6656	1.0866	2.5558	58
3	1.0645	2.9168	1.0715	2.7841	1.0789	2.6637	1.0868	2.5540	57
4	1.0646	2.9145	1.0716	2.7820	1.0790	2.6618	1.0869	2.5523	56
5	1.0647	2.9122	1.0717	2.7799	1.0792	2.6599	1.0870	2.5506	55
6	1.0648	2.9098	1.0719	2.7778	1.0793	2.6580	1.0872	2.5488	54
7	1.0650	2.9075	1.0720	2.7757	1.0794	2.6561	1.0873	2.5471	53
8	1.0651	2.9052	1.0721	2.7736	1.0795	2.6542	1.0874	2.5453	52
9	1.0652	2.9029	1.0722	2.7715	1.0797	2.6523	1.0876	2.5436	51
10	1.0653	2.9006	1.0723	2.7694	1.0798	2.6504	1.0877	2.5419	50
11	1.0654	2.8983	1.0725	2.7674	1.0799	2.6485	1.0878	2.5402	49
12	1.0655	2.8960	1.0726	2.7653	1.0801	2.6466	1.0880	2.5384	48
13	1.0656	2.8937	1.0727	2.7632	1.0802	2.6447	1.0881	2.5367	47
14	1.0658	2.8915	1.0728	2.7611	1.0803	2.6428	1.0882	2.5350	46
15	1.0659	2.8892	1.0729	2.7591	1.0804	2.6410	1.0884	2.5333	45
16	1.0660	2.8869	1.0731	2.7570	1.0806	2.6391	1.0885	2.5316	44
17	1.0661	2.8846	1.0732	2.7550	1.0807	2.6372	1.0886	2.5299	43
18	1.0662	2.8824	1.0733	2.7529	1.0808	2.6353	1.0888	2.5281	42
19	1.0663	2.8801	1.0734	2.7509	1.0810	2.6335	1.0889	2.5264	41
20	1.0664	2.8778	1.0736	2.7488	1.0811	2.6316	1.0891	2.5247	40
21	1.0666	2.8756	1.0737	2.7468	1.0812	2.6297	1.0892	2.5230	39
22	1.0667	2.8733	1.0738	2.7447	1.0813	2.6279	1.0893	2.5213	38
23	1.0668	2.8711	1.0739	2.7427	1.0815	2.6260	1.0895	2.5196	37
24	1.0669	2.8688	1.0740	2.7406	1.0816	2.6242	1.0896	2.5179	36
25	1.0670	2.8666	1.0742	2.7386	1.0817	2.6223	1.0897	2.5163	35
26	1.0671	2.8644	1.0743	2.7366	1.0819	2.6205	1.0899	2.5146	34
27	1.0673	2.8621	1.0744	2.7346	1.0820	2.6186	1.0900	2.5129	33
28	1.0674	2.8599	1.0745	2.7325	1.0821	2.6168	1.0902	2.5112	32
29	1.0675	2.8577	1.0747	2.7305	1.0823	2.6150	1.0903	2.5095	31
30	1.0676	2.8554	1.0748	2.7285	1.0824	2.6131	1.0904	2.5078	30
31	1.0677	2.8532	1.0749	2.7265	1.0825	2.6113	1.0906	2.5062	29
32	1.0678	2.8510	1.0750	2.7245	1.0826	2.6095	1.0907	2.5045	28
33	1.0679	2.8488	1.0751	2.7225	1.0828	2.6076	1.0908	2.5028	27
34	1.0681	2.8466	1.0753	2.7205	1.0829	2.6058	1.0910	2.5011	26
35	1.0682	2.8444	1.0754	2.7185	1.0830	2.6040	1.0911	2.4995	25
36	1.0683	2.8422	1.0755	2.7165	1.0832	2.6022	1.0913	2.4978	24
37	1.0684	2.8400	1.0756	2.7145	1.0833	2.6003	1.0914	2.4961	23
38	1.0685	2.8378	1.0758	2.7125	1.0834	2.5985	1.0915	2.4945	22
39	1.0686	2.8356	1.0759	2.7105	1.0836	2.5967	1.0917	2.4928	21
40	1.0688	2.8334	1.0760	2.7085	1.0837	2.5949	1.0918	2.4912	20
41	1.0689	2.8312	1.0761	2.7065	1.0838	2.5931	1.0920	2.4895	19
42	1.0690	2.8290	1.0763	2.7045	1.0840	2.5913	1.0921	2.4879	18
43	1.0691	2.8269	1.0764	2.7026	1.0841	2.5895	1.0922	2.4862	17
44	1.0692	2.8247	1.0765	2.7006	1.0842	2.5877	1.0924	2.4846	16
45	1.0694	2.8225	1.0766	2.6986	1.0844	2.5859	1.0925	2.4829	15
46	1.0695	2.8204	1.0768	2.6967	1.0845	2.5841	1.0927	2.4813	14
47	1.0696	2.8182	1.0769	2.6947	1.0846	2.5823	1.0928	2.4797	13
48	1.0697	2.8160	1.0770	2.6927	1.0847	2.5805	1.0929	2.4780	12
49	1.0698	2.8139	1.0771	2.6908	1.0849	2.5787	1.0931	2.4764	11
50	1.0699	2.8117	1.0773	2.6888	1.0850	2.5770	1.0932	2.4748	10
51	1.0701	2.8096	1.0774	2.6869	1.0851	2.5752	1.0934	2.4731	9
52	1.0702	2.8074	1.0775	2.6849	1.0853	2.5734	1.0935	2.4715	8
53	1.0703	2.8053	1.0776	2.6830	1.0854	2.5716	1.0936	2.4699	7
54	1.0704	2.8032	1.0778	2.6810	1.0855	2.5699	1.0938	2.4683	6
55	1.0705	2.8010	1.0779	2.6791	1.0857	2.5681	1.0939	2.4666	5
56	1.0707	2.7989	1.0780	2.6772	1.0858	2.5663	1.0941	2.4650	4
57	1.0708	2.7968	1.0781	2.6752	1.0859	2.5646	1.0942	2.4634	3
58	1.0709	2.7947	1.0783	2.6733	1.0861	2.5628	1.0943	2.4618	2
59	1.0710	2.7925	1.0784	2.6714	1.0862	2.5610	1.0945	2.4602	1
60	1.0711	2.7904	1.0785	2.6695	1.0864	2.5593	1.0946	2.4586	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	69°		68°		67°		66°		

′	24° Sec.	24° Co-sec.	25° Sec.	25° Co-sec.	26° Sec.	26° Co-sec.	27° Sec.	27° Co-sec.	′
0	1.0946	2.4586	1.1034	2.3662	1.1126	2.2812	1.1223	2.2027	60
1	1.0948	2.4570	1.1035	2.3647	1.1127	2.2798	1.1225	2.2014	59
2	1.0949	2.4554	1.1037	2.3632	1.1129	2.2784	1.1226	2.2002	58
3	1.0951	2.4538	1.1038	2.3618	1.1131	2.2771	1.1228	2.1989	57
4	1.0952	2.4522	1.1040	2.3603	1.1132	2.2757	1.1230	2.1977	56
5	1.0953	2.4506	1.1041	2.3588	1.1134	2.2744	1.1231	2.1964	55
6	1.0955	2.4490	1.1043	2.3574	1.1135	2.2730	1.1233	2.1952	54
7	1.0956	2.4474	1.1044	2.3559	1.1137	2.2717	1.1235	2.1939	53
8	1.0958	2.4458	1.1046	2.3544	1.1139	2.2703	1.1237	2.1927	52
9	1.0959	2.4442	1.1047	2.3530	1.1140	2.2690	1.1238	2.1914	51
10	1.0961	2.4426	1.1049	2.3515	1.1142	2.2676	1.1240	2.1902	50
11	1.0962	2.4411	1.1050	2.3501	1.1143	2.2663	1.1242	2.1889	49
12	1.0963	2.4395	1.1052	2.3486	1.1145	2.2650	1.1243	2.1877	48
13	1.0965	2.4379	1.1053	2.3472	1.1147	2.2636	1.1245	2.1865	47
14	1.0966	2.4363	1.1055	2.3457	1.1148	2 2623	1.1247	2.1852	46
15	1.0968	2.4347	1.1056	2.3443	1.1150	2.2610	1.1248	2.1840	45
16	1.0969	2.4332	1.1058	2.3428	1.1151	2.2596	1.1250	2.1828	44
17	1.0971	2.4316	1.1059	2.3414	1.1153	2.2583	1.1252	2.1815	43
18	1.0972	2.4300	1.1061	2.3399	1.1155	2.2570	1.1253	2.1803	42
19	1.0973	2.4285	1.1062	2.3385	1.1156	2.2556	1.1255	2.1791	41
20	1.0975	2.4269	1.1064	2.3371	1.1158	2.2543	1.1257	2.1778	40
21	1.0976	2.4254	1.1065	2.3356	1.1159	2.2530	1.1258	2.1766	39
22	1.0978	2.4238	1.1067	2.3342	1.1161	2.2517	1.1260	2.1754	38
23	1.0979	2.4222	1.1068	2.3328	1.1163	2.2503	1.1262	2.1742	37
24	1.0981	2.4207	1.1070	2.3313	1.1164	2.2490	1.1264	2.1730	36
25	1.0982	2.4191	1.1072	2.3299	1.1166	2.2477	1.1265	2.1717	35
26	1.0984	2.4176	1.1073	2.3285	1.1167	2.2464	1.1267	2.1705	34
27	1.0985	2.4160	1.1075	2.3271	1.1169	2.2451	1.1269	2.1693	33
28	1.0986	2.4145	1.1076	2.3256	1.1171	2.2438	1.1270	2.1681	32
29	1.0988	2.4130	1.1078	2.3242	1.1172	2.2425	1.1272	2.1669	31
30	1.0989	2.4114	1.1079	2.3228	1.1174	2.2411	1.1274	2.1657	30
31	1.0991	2.4099	1.1081	2.3214	1.1176	2.2398	1.1275	2.1645	29
32	1.0992	2.4083	1.1082	2.3200	1.1177	2.2385	1.1277	2.1633	28
33	1.0994	2.4068	1.1084	2.3186	1.1179	2.2372	1.1279	2.1620	27
34	1.0995	2.4053	1.1085	2.3172	1.1180	2.2359	1.1281	2.1608	26
35	1.0997	2.4037	1.1087	2.3158	1.1182	2.2346	1.1282	2.1596	25
36	1.0998	2.4022	1.1088	2.3143	1.1184	2.2333	1.1284	2.1584	24
37	1.1000	2.4007	1.1090	2.3129	1.1185	2.2320	1.1286	2.1572	23
38	1.1001	2.3992	1.1092	2.3115	1.1187	2.2307	1.1287	2.1560	22
39	1.1003	2.3976	1.1093	2.3101	1.1189	2.2294	1.1289	2.1548	21
40	1.1004	2.3961	1.1095	2.3087	1.1190	2.2282	1.1291	2.1536	20
41	1.1005	2.3946	1.1096	2.3073	1.1192	2.2269	1.1293	2.1525	19
42	1.1007	2.3931	1.1098	2.3059	1.1193	2.2256	1.1294	2.1513	18
43	1.1008	2.3916	1.1099	2.3046	1.1195	2.2243	1.1296	2.1501	17
44	1.1010	2.3901	1.1101	2.3032	1.1197	2.2230	1.1298	2.1489	16
45	1.1011	2.3886	1.1102	2.3018	1.1198	2.2217	1.1299	2.1477	15
46	1.1013	2.3871	1.1104	2.3004	1.1200	2.2204	1.1301	2.1465	14
47	1.1014	2.3856	1.1106	2.2990	1.1202	2.2192	1.1303	2.1453	13
48	1.1016	2.3841	1.1107	2.2976	1.1203	2.2179	1.1305	2.1441	12
49	1.1017	2.3826	1.1109	2.2962	1.1205	2.2166	1.1306	2.1430	11
50	1.1019	2.3811	1.1110	2.2949	1.1207	2.2153	1.1308	2.1418	10
51	1.1020	2.3796	1.1112	2.2935	1.1208	2.2141	1.1310	2.1406	9
52	1.1022	2.3781	1.1113	2.2921	1.1210	2.2128	1.1312	2.1394	8
53	1.1023	2.3766	1.1115	2.2907	1.1212	2.2115	1.1313	2.1382	7
54	1.1025	2.3751	1.1116	2.2894	1.1213	2.2103	1.1315	2.1371	6
55	1.1026	2.3736	1.1118	2.2880	1.1215	2.2090	1.1317	2.1359	5
56	1.1028	2.3721	1.1120	2.2866	1.1217	2.2077	1.1319	2.1347	4
57	1.1029	2.3706	1.1121	2.2853	1.1218	2.2065	1.1320	2.1335	3
58	1.1031	2.3691	1.1123	2.2839	1.1220	2.2052	1.1322	2.1324	2
59	1.1032	2.3677	1.1124	2.2825	1.1222	2.2030	1.1324	2.1312	1
60	1.1034	2.3662	1.1126	2.2812	1.1223	2.2027	1.1326	2.1300	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	65°		64°		63°		62°		

′	28° Sec.	28° Co-sec.	29° Sec.	29° Co-sec.	30° Sec.	30° Co-sec.	31° Sec.	31° Co-sec.	′
0	1.1326	2.1300	1.1433	2.0627	1.1547	2.0000	1.1666	1.9416	60
1	1.1327	2.1289	1.1435	2.0616	1.1549	1.9990	1.1668	1.9407	59
2	1.1329	2.1277	1.1437	2.0605	1.1551	1.9980	1.1670	1.9397	58
3	1.1331	2.1266	1.1439	2.0594	1.1553	1.9970	1.1672	1.9388	57
4	1.1333	2.1254	1.1441	2.0583	1.1555	1.9960	1.1674	1.9378	56
5	1.1334	2.1242	1.1443	2.0573	1.1557	1.9950	1.1676	1.9369	55
6	1.1336	2.1231	1.1445	2.0562	1.1559	1.9940	1.1678	1.9360	54
7	1.1338	2.1219	1.1446	2.0551	1.1561	1.9930	1.1681	1.9350	53
8	1.1340	2.1208	1.1448	2.0540	1.1562	1.9920	1.1683	1.9341	52
9	1.1341	2.1196	1.1450	2.0530	1.1564	1.9910	1.1685	1.9332	51
10	1.1343	2.1185	1.1452	2.0519	1.1566	1.9900	1.1687	1.9322	50
11	1.1345	2.1173	1.1454	2.0508	1.1568	1.9890	1.1689	1.9313	49
12	1.1347	2.1162	1.1456	2.0498	1.1570	1.9880	1.1691	1.9304	48
13	1.1349	2.1150	1.1458	2.0487	1.1572	1.9870	1.1693	1.9295	47
14	1.1350	2.1139	1.1459	2.0476	1.1574	1.9860	1.1695	1.9285	46
15	1.1352	2.1127	1.1461	2.0466	1.1576	1.9850	1.1697	1.9276	45
16	1.1354	2.1116	1.1463	2.0455	1.1578	1.9840	1.1699	1.9267	44
17	1.1356	2.1104	1.1465	2.0444	1.1580	1.9830	1.1701	1.9258	43
18	1.1357	2.1093	1.1467	2.0434	1.1582	1.9820	1.1703	1.9248	42
19	1.1359	2.1082	1.1469	2.0423	1.1584	1.9811	1.1705	1.9239	41
20	1.1361	2.1070	1.1471	2.0413	1.1586	1.9801	1.1707	1.9230	40
21	1.1363	2.1059	1.1473	2.0402	1.1588	1.9791	1.1709	1.9221	39
22	1.1365	2.1048	1.1474	2.0392	1.1590	1.9781	1.1712	1.9212	38
23	1.1366	2.1036	1.1476	2.0381	1.1592	1.9771	1.1714	1.9203	37
24	1.1368	2.1025	1.1478	2.0370	1.1594	1.9761	1.1716	1.9193	36
25	1.1370	2.1014	1.1480	2.0360	1.1596	1.9752	1.1718	1.9184	35
26	1.1372	2.1002	1.1482	2.0349	1.1598	1.9742	1.1720	1.9175	34
27	1.1373	2.0991	1.1484	2.0339	1.1600	1.9732	1.1722	1.9166	33
28	1.1375	2.0980	1.1486	2.0329	1.1602	1.9722	1.1724	1.9157	32
29	1.1377	2.0969	1.1488	2.0318	1.1604	1.9713	1.1726	1.9148	31
30	1.1379	2.0957	1.1489	2.0308	1.1606	1.9703	1.1728	1.9139	30
31	1.1381	2.0946	1.1491	2.0297	1.1608	1.9693	1.1730	1.9130	29
32	1.1382	2.0935	1.1493	2.0287	1.1610	1.9683	1.1732	1.9121	28
33	1.1384	2.0924	1.1495	2.0276	1.1612	1.9674	1.1734	1.9112	27
34	1.1386	2.0912	1.1497	2.0266	1.1614	1.9664	1.1737	1.9102	26
35	1.1388	2.0901	1.1499	2.0256	1.1616	1.9654	1.1739	1.9093	25
36	1.1390	2.0890	1.1501	2.0245	1.1618	1.9645	1.1741	1.9084	24
37	1.1391	2.0879	1.1503	2.0235	1.1620	1.9635	1.1743	1.9075	23
38	1.1393	2.0868	1.1505	2.0224	1.1622	1.9625	1.1745	1.9066	22
39	1.1395	2.0857	1.1507	2.0214	1.1624	1.9616	1.1747	1.9057	21
40	1.1397	2.0846	1.1508	2.0204	1.1626	1.9606	1.1749	1.9048	20
41	1.1399	2.0835	1.1510	2.0194	1.1628	1.9596	1.1751	1.9039	19
42	1.1401	2.0824	1.1512	2.0183	1.1630	1.9587	1.1753	1.9030	18
43	1.1402	2.0812	1.1514	2.0173	1.1632	1.9577	1.1756	1.9021	17
44	1.1404	2.0801	1.1516	2.0163	1.1634	1.9568	1.1758	1.9013	16
45	1.1406	2.0790	1.1518	2.0152	1.1636	1.9558	1.1760	1.9004	15
46	1.1408	2.0779	1.1520	2.0142	1.1638	1.9549	1.1762	1.8995	14
47	1.1410	2.0768	1.1522	2.0132	1.1640	1.9539	1.1764	1.8986	13
48	1.1411	2.0757	1.1524	2.0122	1.1642	1.9530	1.1766	1.8977	12
49	1.1413	2.0746	1.1526	2.0111	1.1644	1.9520	1.1768	1.8968	11
50	1.1415	2.0735	1.1528	2.0101	1.1646	1.9510	1.1770	1.8959	10
51	1.1417	2.0725	1.1530	2.0091	1.1648	1.9501	1.1772	1.8950	9
52	1.1419	2.0714	1.1531	2.0081	1.1650	1.9491	1.1775	1.8941	8
53	1.1421	2.0703	1.1533	2.0071	1.1652	1.9482	1.1777	1.8932	7
54	1.1422	2.0692	1.1535	2.0061	1.1654	1.9473	1.1779	1.8924	6
55	1.1424	2.0681	1.1537	2.0050	1.1656	1.9463	1.1781	1.8915	5
56	1.1426	2.0670	1.1539	2.0040	1.1658	1.9454	1.1783	1.8906	4
57	1.1428	2.0659	1.1541	2.0030	1.1660	1.9444	1.1785	1.8897	3
58	1.1430	2.0648	1.1543	2.0020	1.1662	1.9435	1.1787	1.8888	2
59	1.1432	2.0637	1.1545	2.0010	1.1664	1.9425	1.1790	1.8879	1
60	1.1433	2.0627	1.1547	2.0000	1.1666	1.9416	1.1792	1.8871	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	61°		60°		59°		58°		

′	32° Sec.	32° Co-sec.	33° Sec.	33° Co-sec.	34° Sec.	34° Co-sec.	35° Sec.	35° Co-sec.	′
0	1.1792	1.8871	1.1924	1.8361	1.2062	1.7883	1.2208	1.7434	60
1	1.1794	1.8862	1.1926	1.8352	1.2064	1.7875	1.2210	1.7427	59
2	1.1796	1.8853	1.1928	1.8344	1.2067	1.7867	1.2213	1.7420	58
3	1.1798	1.8844	1.1930	1.8336	1.2069	1.7860	1.2215	1.7413	57
4	1.1800	1.8836	1.1933	1.8328	1.2072	1.7852	1.2218	1.7405	56
5	1.1802	1.8827	1.1935	1.8320	1.2074	1.7844	1.2220	1.7398	55
6	1.1805	1.8818	1.1937	1.8311	1.2076	1.7837	1.2223	1.7391	54
7	1.1807	1.8809	1.1939	1.8303	1.2079	1.7829	1.2225	1.7384	53
8	1.1809	1.8801	1.1942	1.8295	1.2081	1.7821	1.2228	1.7377	52
9	1.1811	1.8792	1.1944	1.8287	1.2083	1.7814	1.2230	1.7369	51
10	1.1813	1.8783	1.1946	1.8279	1.2086	1.7806	1.2233	1.7362	50
11	1.1815	1.8785	1.1948	1.8271	1.2088	1.7798	1.2235	1.7355	49
12	1.1818	1.8760	1.1951	1.8263	1.2091	1.7791	1.2238	1.7348	48
13	1.1820	1.8757	1.1953	1.8255	1.2093	1.7783	1.2240	1.7341	47
14	1.1822	1.8749	1.1955	1.8246	1.2095	1.7776	1.2243	1.7334	46
15	1.1824	1.8740	1.1958	1.8238	1.2098	1.7768	1.2245	1.7327	45
16	1.1826	1.8731	1.1960	1.8230	1.2100	1.7760	1.2248	1.7319	44
17	1.1828	1.8723	1.1962	1.8222	1.2103	1.7753	1.2250	1.7312	43
18	1.1831	1.8714	1.1964	1.8214	1.2105	1.7745	1.2253	1.7305	42
19	1.1833	1.8706	1.1967	1.8206	1.2107	1.7738	1.2255	1.7298	41
20	1.1835	1.8697	1.1969	1.8198	1.2110	1.7730	1.2258	1.7291	40
21	1.1837	1.8688	1.1971	1.8190	1.2112	1.7723	1.2260	1.7284	39
22	1.1839	1.8680	1.1974	1.8182	1.2115	1.7715	1.2263	1.7277	38
23	1.1841	1.8671	1.1976	1.8174	1.2117	1.7708	1.2265	1.7270	37
24	1.1844	1.8663	1.1978	1.8166	1.2119	1.7700	1.2268	1.7263	36
25	1.1846	1.8654	1.1980	1.8158	1.2122	1.7693	1.2270	1.7256	35
26	1.1848	1.8646	1.1983	1.8150	1.2124	1.7685	1.2273	1.7249	34
27	1.1850	1.8637	1.1985	1.8142	1.2127	1.7678	1.2276	1.7242	33
28	1.1852	1.8629	1.1987	1.8134	1.2129	1.7670	1.2278	1.7234	32
29	1.1855	1.8620	1.1990	1.8126	1.2132	1.7663	1.2281	1.7227	31
30	1.1857	1.8611	1.1992	1.8118	1.2134	1.7655	1.2283	1.7220	30
31	1.1859	1.8603	1.1994	1.8110	1.2136	1.7648	1.2286	1.7213	29
32	1.1861	1.8595	1.1997	1.8102	1.2139	1.7640	1.2288	1.7206	28
33	1.1863	1.8586	1.1999	1.8094	1.2141	1.7633	1.2291	1.7199	27
34	1.1866	1.8578	1.2001	1.8086	1.2144	1.7625	1.2293	1.7192	26
35	1.1868	1.8569	1.2004	1.8078	1.2146	1.7618	1.2296	1.7185	25
36	1.1870	1.8561	1.2006	1.8070	1.2149	1.7610	1.2298	1.7178	24
37	1.1872	1.8552	1.2008	1.8062	1.2151	1.7603	1.2301	1.7171	23
38	1.1874	1.8544	1.2010	1.8054	1.2153	1.7596	1.2304	1.7164	22
39	1.1877	1.8535	1.2013	1.8047	1.2156	1.7588	1.2306	1.7157	21
40	1.1879	1.8527	1.2015	1.8039	1.2158	1.7581	1.2309	1.7151	20
41	1.1881	1.8519	1.2017	1.8031	1.2161	1.7573	1.2311	1.7144	19
42	1.1883	1.8510	1.2020	1.8023	1.2163	1.7566	1.2314	1.7137	18
43	1.1886	1.8502	1.2022	1.8015	1.2166	1.7559	1.2316	1.7130	17
44	1.1888	1.8493	1.2024	1.8007	1.2168	1.7551	1.2319	1.7123	16
45	1.1890	1.8485	1.2027	1.7999	1.2171	1.7544	1.2322	1.7116	15
46	1.1892	1.8477	1.2029	1.7992	1.2173	1.7537	1.2324	1.7109	14
47	1.1894	1.8468	1.2031	1.7984	1.2175	1.7529	1.2327	1.7102	13
48	1.1897	1.8460	1.2034	1.7976	1.2178	1.7522	1.2329	1.7095	12
49	1.1899	1.8452	1.2036	1.7968	1.2180	1.7514	1.2332	1.7088	11
50	1.1901	1.8443	1.2039	1.7960	1.2183	1.7507	1.2335	1.7081	10
51	1.1903	1.8435	1.2041	1.7953	1.2185	1.7500	1.2337	1.7075	9
52	1.1906	1.8427	1.2043	1.7945	1.2188	1.7493	1.2340	1.7068	8
53	1.1908	1.8418	1.2046	1.7937	1.2190	1.7485	1.2342	1.7061	7
54	1.1910	1.8410	1.2048	1.7929	1.2193	1.7478	1.2345	1.7054	6
55	1.1912	1.8402	1.2050	1.7921	1.2195	1.7471	1.2348	1.7047	5
56	1.1915	1.8394	1.2053	1.7914	1.2198	1.7463	1.2350	1.7040	4
57	1.1917	1.8385	1.2055	1.7906	1.2200	1.7456	1.2353	1.7033	3
58	1.1919	1.8377	1.2057	1.7898	1.2203	1.7449	1.2355	1.7027	2
59	1.1921	1.8369	1.2060	1.7891	1.2205	1.7442	1.2358	1.7020	1
60	1.1922	1.8361	1.2062	1.7883	1.2208	1.7434	1.2361	1.7013	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	57°		56°		55°		54°		

′	36° Sec.	36° Co-sec.	37° Sec.	37° Co-sec.	38° Sec.	38° Co-sec.	39° Sec.	39° Co-sec.	′
0	1.2361	1.7013	1.2521	1.6616	1.2690	1.6243	1.2867	1.5890	60
1	1.2363	1.7006	1.2524	1.6610	1.2693	1.6237	1.2871	1.5884	59
2	1.2366	1.6999	1.2527	1.6603	1.2696	1.6231	1.2874	1.5879	58
3	1.2368	1.6993	1.2530	1.6597	1.2699	1.6224	1.2877	1.5873	57
4	1.2371	1.6986	1.2532	1.6591	1.2702	1.6218	1.2880	1.5867	56
5	1.2374	1.6979	1.2535	1.6584	1.2705	1.6212	1.2883	1.5862	55
6	1.2376	1.6972	1.2538	1.6578	1.2707	1.6206	1.2886	1.5856	54
7	1.2379	1.6965	1.2541	1.6572	1.2710	1.6200	1.2889	1.5850	53
8	1.2382	1.6959	1.2543	1.6565	1.2713	1.6194	1.2892	1.5845	52
9	1.2384	1.6952	1.2546	1.6559	1.2716	1.6188	1.2895	1.5839	51
10	1.2387	1.6945	1.2549	1.6552	1.2719	1.6182	1.2898	1.5833	50
11	1.2389	1.6938	1.2552	1.6546	1.2722	1.6176	1.2901	1.5828	49
12	1.2392	1.6932	1.2554	1.6540	1.2725	1.6170	1.2904	1.5822	48
13	1.2395	1.6925	1.2557	1.6533	1.2728	1.6164	1.2907	1.5816	47
14	1.2397	1.6918	1.2560	1.6527	1.2731	1.6159	1.2910	1.5811	46
15	1.2400	1.6912	1.2563	1.6521	1.2734	1.6153	1.2913	1.5805	45
16	1.2403	1.6905	1.2565	1.6514	1.2737	1.6147	1.2916	1.5799	44
17	1.2405	1.6898	1.2568	1.6508	1.2739	1.6141	1.2919	1.5794	43
18	1.2408	1.6891	1.2571	1.6502	1.2742	1.6135	1.2922	1.5788	42
19	1.2411	1.6885	1.2574	1.6496	1.2745	1.6129	1.2926	1.5783	41
20	1.2413	1.6878	1.2577	1.6489	1.2748	1.6123	1.2929	1.5777	40
21	1.2416	1.6871	1.2579	1.6483	1.2751	1.6117	1.2932	1.5771	39
22	1.2419	1.6865	1.2582	1.6477	1.2754	1.6111	1.2935	1.5766	38
23	1.2421	1.6858	1.2585	1.6470	1.2757	1.6105	1.2938	1.5760	37
24	1.2424	1.6851	1.2588	1.6464	1.2760	1.6099	1.2941	1.5755	36
25	1.2427	1.6845	1.2591	1.6458	1.2763	1.6093	1.2944	1.5749	35
26	1.2429	1.6838	1.2593	1.6452	1.2766	1.6087	1.2947	1.5743	34
27	1.2432	1.6831	1.2596	1.6445	1.2769	1.6081	1.2950	1.5738	33
28	1.2435	1.6825	1.2599	1.6439	1.2772	1.6077	1.2953	1.5732	32
29	1.2437	1.6818	1.2602	1.6433	1.2775	1.6070	1.2956	1.5727	31
30	1.2440	1.6812	1.2605	1.6427	1.2778	1.6064	1.2960	1.5721	30
31	1.2443	1.6805	1.2607	1.6420	1.2781	1.6058	1.2963	1.5716	29
32	1.2445	1.6798	1.2610	1.6414	1.2784	1.6052	1.2966	1.5710	28
33	1.2448	1.6792	1.2613	1.6408	1.2787	1.6046	1.2969	1.5705	27
34	1.2451	1.6785	1.2616	1.6402	1.2790	1.6040	1.2972	1.5699	26
35	1.2453	1.6779	1.2619	1.6396	1.2793	1.6034	1.2975	1.5694	25
36	1.2456	1.6772	1.2622	1.6389	1.2795	1.6029	1.2978	1.5688	24
37	1.2459	1.6766	1.2624	1.6383	1.2798	1.6023	1.2981	1.5683	23
38	1.2461	1.6759	1.2627	1.6377	1.2801	1.6017	1.2985	1.5677	22
39	1.2464	1.6752	1.2630	1.6371	1.2804	1.6011	1.2988	1.5672	21
40	1.2467	1.6746	1.2633	1.6365	1.2807	1.6005	1.2991	1.5666	20
41	1.2470	1.6739	1.2636	1.6359	1.2810	1.6000	1.2994	1.5661	19
42	1.2472	1.6733	1.2639	1.6352	1.2813	1.5994	1.2997	1.5655	18
43	1.2475	1.6726	1.2641	1.6346	1.2816	1.5988	1.3000	1.5650	17
44	1.2478	1.6720	1.2644	1.6340	1.2819	1.5982	1.3003	1.5644	16
45	1.2480	1.6713	1.2647	1.6334	1.2822	1.5976	1.3006	1.5639	15
46	1.2483	1.6707	1.2650	1.6328	1.2825	1.5971	1.3010	1.5633	14
47	1.2486	1.6700	1.2653	1.6322	1.2828	1.5965	1.3013	1.5628	13
48	1.2488	1.6694	1.2656	1.6316	1.2831	1.5959	1.3016	1.5622	12
49	1.2490	1.6687	1.2659	1.6309	1.2834	1.5953	1.3019	1.5617	11
50	1.2494	1.6681	1.2661	1.6303	1.2837	1.5947	1.3022	1.5611	10
51	1.2497	1.6674	1.2664	1.6297	1.2840	1.5942	1.3025	1.5606	9
52	1.2499	1.6668	1.2667	1.6291	1.2843	1.5936	1.3029	1.5600	8
53	1.2502	1.6661	1.2670	1.6285	1.2846	1.5930	1.3032	1.5595	7
54	1.2505	1.6655	1.2673	1.6279	1.2849	1.5924	1.3035	1.5590	6
55	1.2508	1.6648	1.2676	1.6273	1.2852	1.5919	1.3038	1.5584	5
56	1.2510	1.6642	1.2679	1.6267	1.2855	1.5913	1.3041	1.5579	4
57	1.2513	1.6636	1.2681	1.6261	1.2858	1.5907	1.3044	1.5573	3
58	1.2516	1.6629	1.2684	1.6255	1.2861	1.5901	1.3048	1.5568	2
59	1.2519	1.6623	1.2687	1.6249	1.2864	1.5896	1.3051	1.5563	1
60	1.2521	1.6616	1.2690	1.6243	1.2867	1.5890	1.3054	1.5557	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	53°		52°		51°		50°		

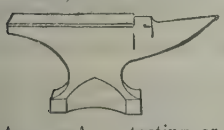
′	40° Sec.	40° Co-sec.	41° Sec.	41° Co-sec.	42° Sec.	42° Co-sec.	43° Sec.	43° Co-sec.	′
0	1.3054	1.5557	1.3250	1.5242	1.3456	1.4945	1.3673	1.4663	60
1	1.3057	1.5552	1.3253	1.5237	1.3460	1.4940	1.3677	1.4658	59
2	1.3060	1.5546	1.3257	1.5232	1.3463	1.4935	1.3681	1.4654	58
3	1.3064	1.5541	1.3260	1.5227	1.3467	1.4930	1.3684	1.4649	57
4	1.3067	1.5536	1.3263	1.5222	1.3470	1.4925	1.3688	1.4644	56
5	1.3070	1.5530	1.3267	1.5217	1.3474	1.4921	1.3692	1.4640	55
6	1.3073	1.5525	1.3270	1.5212	1.3477	1.4916	1.3695	1.4635	54
7	1.3076	1.5520	1.3274	1.5207	1.3481	1.4911	1.3699	1.4631	53
8	1.3080	1.5514	1.3277	1.5202	1.3485	1.4906	1.3703	1.4626	52
9	1.3083	1.5509	1.3280	1.5197	1.3488	1.4901	1.3707	1.4622	51
10	1.3086	1.5503	1.3284	1.5192	1.3492	1.4897	1.3710	1.4617	50
11	1.3089	1.5498	1.3287	1.5187	1.3495	1.4892	1.3714	1.4613	49
12	1.3092	1.5493	1.3290	1.5182	1.3499	1.4887	1.3718	1.4608	48
13	1.3096	1.5487	1.3294	1.5177	1.3502	1.4882	1.3722	1.4604	47
14	1.3099	1.5482	1.3297	1.5171	1.3506	1.4877	1.3725	1.4599	46
15	1.3102	1.5477	1.3301	1.5166	1.3509	1.4873	1.3729	1.4595	45
16	1.3105	1.5471	1.3304	1.5161	1.3513	1.4868	1.3733	1.4590	44
17	1.3109	1.5466	1.3307	1.5156	1.3517	1.4863	1.3737	1.4586	43
18	1.3112	1.5461	1.3311	1.5151	1.3520	1.4858	1.3740	1.4581	42
19	1.3115	1.5456	1.3314	1.5146	1.3524	1.4854	1.3744	1.4577	41
20	1.3118	1.5450	1.3318	1.5141	1.3527	1.4849	1.3748	1.4572	40
21	1.3121	1.5445	1.3321	1.5136	1.3531	1.4844	1.3752	1.4568	39
22	1.3125	1.5440	1.3324	1.5131	1.3534	1.4839	1.3756	1.4563	38
23	1.3128	1.5434	1.3328	1.5126	1.3538	1.4835	1.3759	1.4559	37
24	1.3131	1.5429	1.3331	1.5121	1.3542	1.4830	1.3763	1.4554	36
25	1.3134	1.5424	1.3335	1.5116	1.3545	1.4825	1.3767	1.4550	35
26	1.3138	1.5419	1.3338	1.5111	1.3549	1.4821	1.3771	1.4545	34
27	1.3141	1.5413	1.3342	1.5106	1.3552	1.4816	1.3774	1.4541	33
28	1.3144	1.5408	1.3345	1.5101	1.3556	1.4811	1.3778	1.4536	32
29	1.3148	1.5403	1.3348	1.5096	1.3560	1.4806	1.3782	1.4532	31
30	1.3151	1.5398	1.3352	1.5092	1.3563	1.4802	1.3786	1.4527	30
31	1.3154	1.5392	1.3355	1.5087	1.3567	1.4797	1.3790	1.4523	29
32	1.3157	1.5387	1.3359	1.5082	1.3571	1.4792	1.3794	1.4518	28
33	1.3161	1.5382	1.3362	1.5077	1.3574	1.4788	1.3797	1.4514	27
34	1.3164	1.5377	1.3366	1.5072	1.3578	1.4783	1.3801	1.4510	26
35	1.3167	1.5371	1.3369	1.5067	1.3581	1.4778	1.3805	1.4505	25
36	1.3170	1.5366	1.3372	1.5062	1.3585	1.4774	1.3809	1.4501	24
37	1.3174	1.5361	1.3376	1.5057	1.3589	1.4769	1.3813	1.4496	23
38	1.3177	1.5356	1.3379	1.5052	1.3592	1.4764	1.3816	1.4492	22
39	1.3180	1.5351	1.3383	1.5047	1.3596	1.4760	1.3820	1.4487	21
40	1.3184	1.5345	1.3386	1.5042	1.3600	1.4755	1.3824	1.4483	20
41	1.3187	1.5340	1.3390	1.5037	1.3603	1.4750	1.3828	1.4479	19
42	1.3190	1.5335	1.3393	1.5032	1.3607	1.4746	1.3832	1.4474	18
43	1.3193	1.5330	1.3397	1.5027	1.3611	1.4741	1.3836	1.4470	17
44	1.3197	1.5325	1.3400	1.5022	1.3614	1.4736	1.3839	1.4465	16
45	1.3200	1.5319	1.3404	1.5018	1.3618	1.4732	1.3843	1.4461	15
46	1.3203	1.5314	1.3407	1.5013	1.3622	1.4727	1.3847	1.4457	14
47	1.3207	1.5309	1.3411	1.5008	1.3625	1.4723	1.3851	1.4452	13
48	1.3210	1.5304	1.3414	1.5003	1.3629	1.4718	1.3855	1.4448	12
49	1.3213	1.5299	1.3418	1.4998	1.3633	1.4713	1.3859	1.4443	11
50	1.3217	1.5294	1.3421	1.4993	1.3636	1.4709	1.3863	1.4439	10
51	1.3220	1.5289	1.3425	1.4988	1.3640	1.4704	1.3867	1.4435	9
52	1.3223	1.5283	1.3428	1.4983	1.3644	1.4699	1.3870	1.4430	8
53	1.3227	1.5278	1.3432	1.4979	1.3647	1.4695	1.3874	1.4426	7
54	1.3230	1.5273	1.3435	1.4974	1.3651	1.4690	1.3878	1.4422	6
55	1.3233	1.5268	1.3439	1.4969	1.3655	1.4686	1.3882	1.4417	5
56	1.3237	1.5263	1.3442	1.4964	1.3658	1.4681	1.3886	1.4413	4
57	1.3240	1.5258	1.3446	1.4959	1.3662	1.4676	1.3890	1.4408	3
58	1.3243	1.5253	1.3449	1.4954	1.3666	1.4672	1.3894	1.4404	2
59	1.3247	1.5248	1.3453	1.4949	1.3669	1.4667	1.3898	1.4400	1
60	1.3250	1.5242	1.3456	1.4945	1.3673	1.4663	1.3902	1.4395	0
′	49° Co-sec.	49° Sec.	48° Co-sec.	48° Sec.	47° Co-sec.	47° Sec.	46° Co-sec.	46° Sec.	′

′	44° Sec.	Co-sec.	′	′	44° Sec.	Co-sec.	′	′	44° Sec	Co-sec.	′
0	1.3902	1.4395	60	21	1.3984	1.4305	39	41	1.4065	1.4221	19
1	1.3905	1.4391	59	22	1.3988	1.4301	38	42	1.4069	1.4217	18
2	1.3909	1.4387	58	23	1.3992	1.4297	37	43	1.4073	1.4212	17
3	1.3913	1.4382	57	24	1.3996	1.4292	36	44	1 4077	1.4208	16
4	1.3917	1.4378	56	25	1.4000	1.4288	35	45	1.4081	1.4204	15
5	1.3921	1.4374	55	26	1.4004	1.4284	34	46	1.4085	1.4200	14
6	1.3925	1.4370	54	27	1.4008	1.4280	33	47	1.4089	1.4196	13
7	1.3929	1.4365	53	28	1.4012	1.4276	32	48	1.4093	1.4192	12
8	1.3933	1.4361	52	29	1.4016	1.4271	31	49	1.4097	1.4188	11
9	1.3937	1.4357	51	30	1.4020	1.4267	30	50	1.4101	1.4183	10
10	1 3941	1.4352	50	31	1.4024	1.4263	29	51	1.4105	1.4179	9
11	1.3945	1.4348	49	32	1.4028	1.4259	28	52	1.4109	1.4175	8
12	1.3949	1.4344	48	33	1.4032	1.4254	27	53	1.4113	1.4171	7
13	1.3953	1.4339	47	34	1.4036	1.4250	26	54	1.4117	1.4167	6
14	1.3957	1.4335	46	35	1.4040	1.4246	25	55	1.4122	1.4163	5
15	1.3960	1.4331	45	36	1.4044	1.4242	24	56	1.4126	1.4159	4
16	1.3964	1.4327	44	37	1.4048	1.4238	23	57	1.4130	1.4154	3
17	1.3968	1.4322	43	38	1.4052	1.4233	22	58	1.4134	1.4150	2
18	1.3972	1.4318	42	39	1.4056	1.4229	21	59	1.4138	1.4146	1
19	1.3976	1.4314	41	40	1.4060	1.4225	20	60	1.4142	1.4142	0
20	1.3980	1.4310	40								
′	Co-sec.	Sec.	′	′	Co-sec.	Sec.	′	′	Co-sec.	Sec.	′
	45°				45°				45°		

DICTIONARY OF SHOP TERMS

A

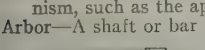
Angle Irons or Plates—Usually castings, for holding work at any desired angle to the cutting tool. Made for use on the face plate of a lathe or table of milling machine, planer, boring mill, etc.



Anvils—Blocks of iron or steel on which metals are hammered or forged. Usually have a steel face. A square hole is usually provided for holding hardies, fuller blocks, etc.

Apron—A protecting or covering plate that encloses any mechanism, such as the apron of a lathe.

Arbor—A shaft or bar for holding *cutting tools*. Frequently has a taper shank fitting the spindle of a machine. The term was formerly used interchangeably with "mandrel" on which *work* is held. See Mandrel.



B

Babbitt Metal—A general name applied to soft bearing metals. Named after man who devised a good tin and copper alloy. Antimony and lead are also frequently used in small quantities in the mixture.

Back Lash—Lost motion in moving parts, such as a screw in its nut or in the teeth of mating gears.

Backing-off—Removing metal behind the cutting edge to relieve friction in cutting, as in taps or reamers.

Back Rest—A rest for supporting slender work in turning or grinding. When the rest follows the cutting tool, it is frequently called a "follow or follower rest."

Balance, Dynamic or Running—Securing the proper distribution of weight so that shafts or pulleys will run without vibration.

Balance, Static or Standing—Distributing the weight of pulleys or shafts so that, when placed on knife-edge ways, they will stand in any position. If unbalanced, the heavy side rolls to the bottom.

Balancing Ways—Level strips or sharp-edged disks for testing shafts or pulleys for standing balance. The disks are usually mounted on ball bearings.

Bastard—Not regular. Seldom used except as applied to a file or thread of irregular cut or shape.

Bearing—The support in which a shaft revolves. May be plain, ball or roller. The latter interpose balls or rollers between the shaft and the support to reduce friction. Frequently called anti-friction bearings.

Bench, Inspection—A bench with a level top, frequently of cast iron, on which finished work can be inspected with surface gages and similar instruments.

Bench, Laying-out—A metal bench or plate having a level metal top, on which work can be laid out for future machining operations. Both of these are sometimes called leveling benches.

Bevel—Any surface not at right angles to the rest of the piece. When at 45 degrees the bevel is frequently called a miter. Name is also given to tool for measuring or laying off bevels. When combined with a scale of degrees, it is called a bevel protractor.

Blocks, "Jo"—Shop name for Johannssen measuring blocks which are very accurate.

Blocks, Hoisting—Any combination pulleys and ropes or chains by which weights are lifted. They are usually hand operated but in some few cases employ either electric or air motors. Differential, planetary or worm gearing is used.

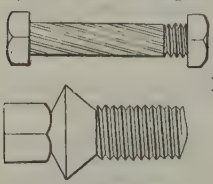


Blow Pipe—A device for mixing a jet of air with a flame both to direct the flame and to increase the heat. The upper picture shows the type used with an alcohol lamp, while the lower mixes both gas and air by means of the pipes and valves shown.

Blow Torch—A portable device for securing intense local heat. Used by plumbers and for similar work.

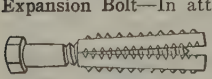
BOLTS

Agricultural Bolt—Agricultural bolts, as indicated by the name, are used in farm machines and appliances. The body of the bolt has a series of helical lands and grooves which are formed by a rolling process.

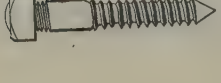


Boiler-patch Bolt—A bolt used in fastening patches on boilers. The patch is countersunk for the cone head, and boiler shell tapped for bolt thread. The square head is knocked off after bolt is in place.

Expansion Bolt—In attaching parts to brick, stone or concrete walls and floors, expansion bolts are frequently employed. The "Star" bolt in the illustration has an internally threaded, split sleeve which is slipped into a hole made in the wall and then expanded by running in the screw.



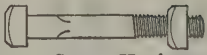
Hanger Bolt—This bolt is used for attaching hangers to woodwork and consists of a lag screw at one end with a machine bolt thread and nut at the other.



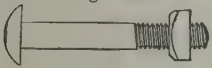
Machine Bolts



Hexagon Head



Square Head

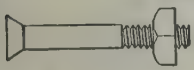


Round Head



Square Countersunk Head

Miscellaneous Bolts



Tire



Loom or Carriage



Oval T-Head



Joint



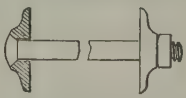
Step



Eye



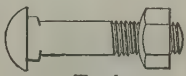
Deck



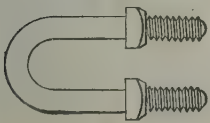
Bridge or Roof



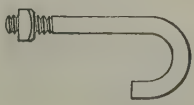
Sink



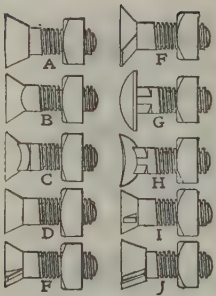
Track



U

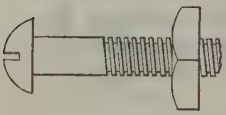


Hook



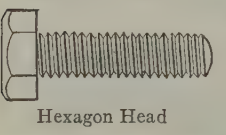
Plow Bolt—Several types of plow and cultivator bolts are shown in the accompanying engravings, the forms illustrated being typical of a variety of bolts manufactured for agricultural apparatus.

A—Large Round Head
B—Square Head
C—Round Head, Square Shank
D—Round Head
E—Key Head
F—Tee Head
G—Button Head
H—Concave Head
I—Reverse Key Head
J—Large Key Head.



Round or Button Head

Stove Bolt—Stove bolts are made in sizes ranging from $\frac{1}{8}$ to $\frac{3}{8}$ inch. The heads commonly formed are the round, or button head, and the flat or countersunk head.

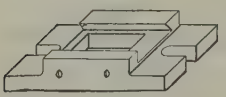


Hexagon Head

Tap Bolt—Tap bolts are usually threaded the full length of the body, which is not machined prior to running on the die. Only the point and the under side of the head are finished. They are also made with square heads.

Bolt Cutter—Machine for cutting threads on bolts.

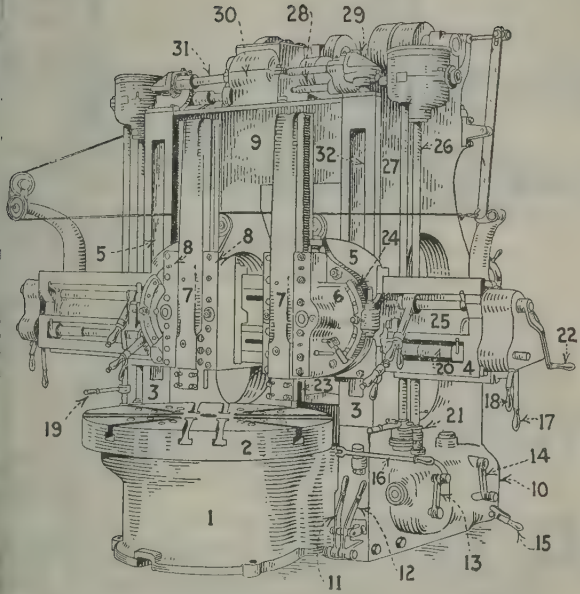
Bolt Header—Machine for upsetting the bolt body to form the head.



Bolster

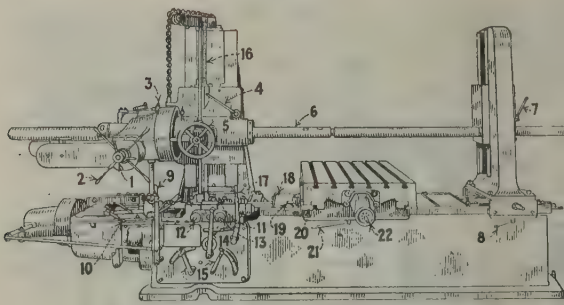
Bolster—A block sometimes called the die block, in which a punch press die is held. It is attached to the bed by bolts at either end.

Boring and Turning Mill—Machine having a rotating horizontal table for the work with one or more stationary vertical tools for boring, turning or facing; a turret often provided for holding a number of tools in one of the heads. Sometimes has a tool head on side rail. Often called "vertical mill." Horizontal boring machines are not usually called "mills."



BORING MILL, VERTICAL

1. Bed.
2. Table.
3. Housing.
4. Rail.
5. Saddle.
6. Swivel.
7. Ram.
8. Swivel clamp.
9. Arch.
10. Feed box.
11. Change gear lever.
12. Back gear lever.
13. Feed reverse lever.
14. Feed back gear lever.
15. Tumbler lever.
16. Start and stop lever.
17. Vertical feed lever.
18. Cross feed lever.
19. Rapid traverse handle.
20. Rail screw.
21. Feed clutch.
22. Crank handle.
23. Tool holder.
24. Swivel segment gear.
25. Feed rod.
26. Feed shaft.
27. Rapid traverse shaft.
28. Horizontal rapid traverse shaft.
29. Elevating gear.
30. Elevating device.
31. Elevating shaft.
32. Elevating screw.



BORING MACHINE, HORIZONTAL

1. Spindle feed clutch.
2. Quick hand spindle movement.
3. Interlocking back gear levers
4. Head locking lever.
5. Slow spindle movement.
6. Spindle.
7. Tail block clamp.
8. Back rest base clamp.
9. Power control lever.
10. Speed change levers.
11. Interlocking feed levers.
12. Hand adjustment for head, micrometer dial.
13. Hand adjustment for sadd micrometer dial.
14. Reverse lever for feed and quic return.
15. Feed change levers.
16. Head elevating screw.
17. Feed and quick return lever.
18. Removable bed guard.
19. Platen feed trip lever.
20. Limit stop to platen.
21. Saddle clamp.
22. Hand adjustment for plate micrometer dial.

Brass—An alloy of copper with zinc and lead.

Brazing—The joining of metals by the use of copper filings chips and borax or some other flux. This is usually call spelter or hard solder and can be applied to almost any of th harder metals.

Brazing Clamps—Clamps to hold the ends of band saw or oth work for brazing.

Broach—A tool which is practically a series of chisels or cuttin edges for enlarging holes or changing their shape. The san name is sometimes given to a small reamer used by jewelers.

Bronzes—Alloys of copper and tin. Used in coinage, bells, stat ary, musical instruments, etc.

Bulldozer—Heavy forming machine for bending iron or steel and which the dies move horizontally. Very similar to a forgi press.

Bull Blocks—Blocks through which wire or rods are drawn to redu size.

Bull Wheel—Usually applied to the gear of a planer which mesh into the rack under the table and drives it.



Bunsen Burner—A device for securing a very hot flame by mixing air and gas in a chamber behind the flame. The one shown has two side pieces which make the flame flat instead of round.

Burnishers—Tools of hardened and polished steel for finishing metals by friction. They are held against the revolving work and give a smooth surface by compressing the outer layer of the metal.

Bushing Tube or shell supported by other material. Hardened bushings are used in jig work to guide drills or other tools. Bushings are frequently used as bearings for revolving shafts.

Butt Joint—A riveted joint with the ends of the plates abutting squarely against each other.

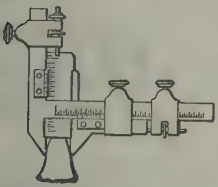
Butt Weld—A weld in which the ends of the two pieces simply abut against each other for welding together.

C

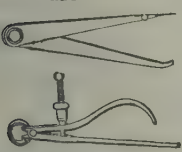
CALIPERS



Firm Joint Calipers—Having a large, firm joint in place of old style plain riveted joint. This shows an inside caliper.

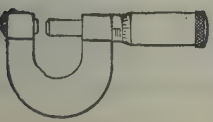


Gear Tooth Caliper—A caliper with two beams at right angles. The vertical beam gives tooth depth to pitch line and the other the thickness at pitch line. Both have verniers. Used in measuring teeth for accuracy.

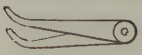


Hermaphrodite Caliper—A combination of one leg of a divider and one leg of a caliper. Used in testing centered work and in laying off distances from the edge of a piece.

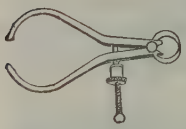
Keyhole Caliper—Has one straight leg and the other curved.



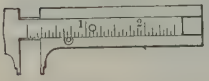
Micrometer Caliper—A measuring instrument consisting of a screw and having its barrel divided into small parts so as to measure slight degrees of rotation. Usually measure to thousandths, sometimes to ten-thousandths.



Odd Leg Caliper—Calipers having both legs pointing in the same direction. Used in measuring shoulder distances on flat work, boring half round, boxes, etc.



Outside, Spring Caliper—Tool for measuring the outside diameter of work. Controlled by spring and threaded nut. Nuts are sometimes split or otherwise designed to allow rapid movement when desired, final adjustment being made by screw.

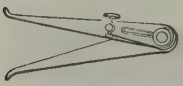


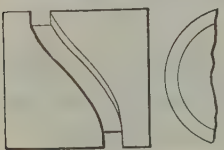
Slide Caliper—A beam caliper made with a graduated slide. Generally made small for carrying in the pocket.



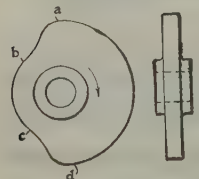
Square-micrometer Caliper—A beam caliper having jaws square with the blade, and having a vernier-micrometer adjustment to read to thousandths of an inch.

Transfer Caliper—Caliper which can be set to a given size, the auxiliary arm set, and the calipers opened at will, as they can be reset to the auxiliary arm at any time. Used to caliper recesses and places where the legs must be moved to get them out.

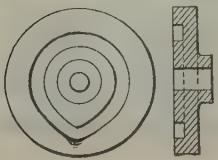




Cam, Drum or Barrel—The drum cam has a path for the roll cut around the periphery, and imparts a to-and-fro motion to a slide or lever in a plane parallel to the axis of the cam. Sometimes these cams are built up of a plain drum with cam plates attached.



Cam, Edge—Edge or peripheral cams (also called disk cams) operate a mechanism in one direction only, gravity, or a spring being relied upon to hold the cam roll in contact with the edge of the cam. On the cam shown, *a* to *b* is the drop; *b* to the dwell; *c* to *d*, rise; *d* to *a*, dwell.



Cam, Face—Face cams have a groove or roll path cut in the face and operate a lever or other mechanism positively in both directions, as the roll is always guided by the sides of the slot.

Carbonizing or Carburizing—The heat treatment of steel so that the outer surface can be hardened. The surface absorbs carbon from the material used.

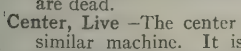
Case-hardening—A surface hardening by which the outer skin of a piece of iron or steel that has absorbed carbon will harden when cooled in water.

Cat Head—A collar or sleeve which fits loosely over a shaft and is clamped to it by set screws. Used for steady rest to run on where it is not desired to run it on the work.

Same name is also given to the head carrying cutters on boring bars.

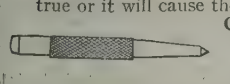
Center, Dead—The back center or the stationary center on which the work revolves. On many grinding machines both centers are dead.

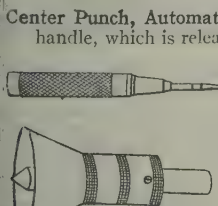
Center, Live—The center in the revolving spindle of a lathe or similar machine. It is highly important that this should run true or it will cause the work to move in an eccentric path.



Center Punch—Punch for marking points on metal. Made of steel with a sharp point and hardened. Often called a prick punch.

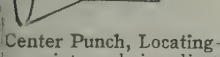
Center Punch, Automatic—Has a spring-actuated hammer in the handle, which is released when the handle is pressed way down. The point can be placed where desired and the blow given by a pressure of the hand. In some cases the blow can be varied.





Center Punch, Bell or Self-centering—A center punch sliding in a bell or cone-mouthed casing so when placed square over the end of any bar it will locate the center with sufficient accuracy for most purposes.

Center Punch, Locating—Having an extra leg which has a spring point and is adjustable. The spring is placed in the first punch mark and so locates the next punch mark at the right distance from the first.



Centering Machines—For drilling and reaming center of work for the lathe or grinder.

Chamber—A long recess. See Recess.

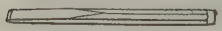
Chasers—Tools used for cutting threads by chasing. Usually have several teeth of right pitch, but name is sometimes applied to a single-point tool used in brass work on a Fox lathe. Chasers are made circular or flat.

Chasing Threads—Cutting threads by moving a single tool along the work at the right speed to give the proper pitch. Distinguishes between threads cut with a die and those cut with a threading tool.

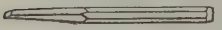
Chattering—Caused by a slight jumping of the tool away from the work or vice-versa, and leaves little ridges on the surface. Due to springing of the tool, work or machine.

Chipping—The cutting of metal with cold chisel and hammer. Also used when a piece "chips" or breaks out of a piece or punch.

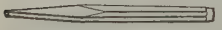
Chisel, Cape—Chisel with a narrow blade for cutting keyways and similar work.



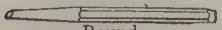
Flat Cold Chisel



Diamond



Cape



Round

Chisel, Cold—Any chisel for cutting cold metal. Name is usually applied to plain flat cold chisel, as in illustration.

Chisel, Diamond or Lozenge—Similar to a cape chisel but with square end and cutting edge at one corner. Used for cutting a sharp-bottomed groove.

Chisel, Round—A round-end chisel with the cutting edge ground back at an angle. Used for cutting oil grooves and similar work.

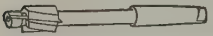
Chuck, Draw—Operated by moving longitudinally in a taper bearing. Used on precision work.

Comparator—Name given to a machine designed by James Hartness to measure screw threads and similar parts by projecting an enlarged shadow on a chart to compare the screw with the desired standard.

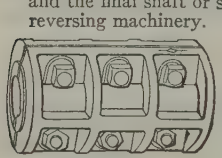
Cotter, Spring—Also called split cotter, split pin, etc. Used in a hole drilled crosswise of a stud, shaft or some similar member, and its ends spread apart to retain it in place and keep some member carried by the shaft from slipping off.



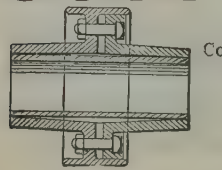
Counterbore—Has a pilot to fit a hole already drilled, or drilled and reamed, and its body with cutting edges on the end is used to enlarge the hole to receive a screw head or body or for some similar purpose.



Countershaft—An intermediate shaft, between the main drive and the final shaft or spindle. Used for starting, stopping and reversing machinery.



Coupling, Clamp—Couplings made in two or more parts, clamping around the shafts by transverse bolts. Hold either by friction or have dowels in shaft. Sometimes called compression although this is confusing.



Coupling, Compression—Grips shafting by drawing together tapered parts. This forces them against shaft and holds it firmly. Bolts parallel with shaft draw parts together.

Coupling, Friction—Couplings which depend on frictional contact.

Coupling, Jaw or Clutch—Positively engaged by jaws or projections on the face of opposing parts.

Coping Machine—For cutting away the flanges and corners of beams and bending the ends.



Counter, Revolution—Device for counting the revolutions of a shaft. Generally made with a worm and a gear having 100 teeth so that one turn of dial equals 100 revolutions.

Crane, Gantry—Traveling cane mounted on posts or legs for yard use.

Crane, Jib—Crane with a swinging boom or arm.

Crane, Locomotive—Crane mounted on a car with an engine so as to be self-propelling on a track.

Crane, Monorail—Traveling crane that is suspended from a single rail. Sometimes carries an operator in a suspended page, or is operated from the floor or a central control point.

Crane, Pillar—Having the boom or moving arm fastened to pillar or post.

Crane, Portable—Hoisting frame on wheels which can be run around to the work and used to handle work in and out of lathes and other machines.

Crane, Post—See Crane, Pillar.

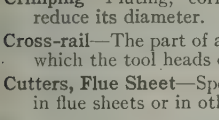
Crane, Traveling—Crane with a bridge or cross-beam having wheels at each end so that it can be run on overhead tracks to any point in the shop.

Crimping—Fluting, corrugating or compressing metal ring to reduce its diameter.

Cross-rail—The part of a planer, boring mill or similar machine on which the tool heads or slides move and are supported.

Cutters, Flue Sheet—Special cutters for making holes, as for flues, in flue sheets or in other sheet metal or structural work.

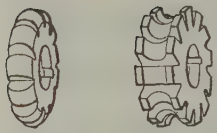
CUTTERS, MILLING



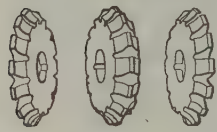
Angular Cutters—Such cutters are used for milling straight and spiral mills, ratchet teeth, etc. Cutters for spiral mill grooving are commonly made with an angle of 12 degrees on one side and 40-, 48- or 53-degree angle on the other.

Cherry—A form of milling cutter which is more strictly a formed reamer, for finishing out the interior of a die or some similar tool. The cherry shown is for a bullet mold.





Convex and Concave Cutters—Convex and concave cutters are used for milling half circles. The convex cutter is often used for fluting taps and other tools. Like all other formed cutters the shape is not affected by the process of sharpening.



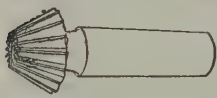
Corner-rounding Cutters—Left-hand, double, and right-hand cutters of this type are used for finishing rounded corners and edges of work. The shape of the cutter is not altered by grinding on the face of the teeth.

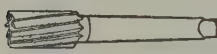


Cotter Mill—This type of mill is used for cutting keyseats and other slots and grooves.



Dovetail Cutters—Inner and outer dovetails are milled with these tools, and edges of work conveniently beveled.





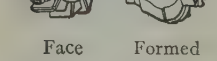
End Mill—This mill, sometimes called a butt mill, is used for machining slots, milling edges of work, cutting cams, etc.



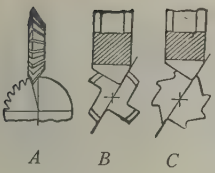


Face and Formed Cutters—The face cutter to the left, of Brown & Sharpe inserted tooth type, is made in large sizes and cuts on the periphery and ends of teeth.

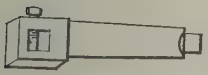
The formed cutter to the right may be sharpened by grinding on the face without changing the shape.

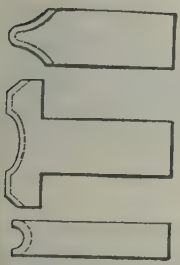


Fish-tail Cutter—A simple cutter for milling a seat or groove in a shaft or other piece. Usually operated at high speed and with a light cut and feed.

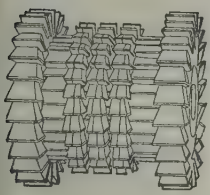


Fluting Cutters—Cutter *A* is an angular mill for cutting the teeth in spiral mills, cutter *B* is for tap fluting and *C* for milling reamer flutes. In each case the cutter is shown with one face set radial to the center of the work. See End Mill.

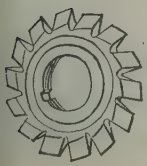




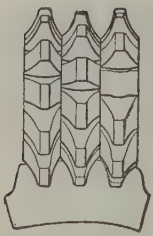
Fly Cutters—Fly cutters are simple formed cutters which may be held in an arbor like that shown at the top of the group. The arbor is placed in the miller spindle and the tool or other work to be formed is given a slow feed past the revolving cutter. After roughing out, the cutter can be held stationary and used like a planer tool for finishing the work which is fed past it and so given a scraping cut.



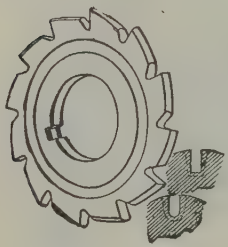
Gang Cutters—Cutters are used in a gang on an arbor for milling a broad surface of any desired form. The cutters shown have interlocking and overlapping teeth so that proper spacing may be maintained. In extensive manufacturing operation the gangs of cutters are usually kept set up on their arbor and never removed except for grinding.



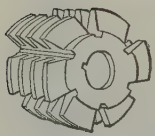
Gear Cutter (Involute)—In the Brown & Sharpe system of involute gear cutters, eight cutters are regularly made for each pitch. Such cutters are always accurately formed and can be sharpened without affecting the shape of the teeth.



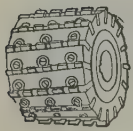
Gear Cutters, Duplex—The Gould & Eberhart duplex cutters are used in gangs of two or more; the number of cutters in the gang depending on the number of teeth in the gear to be cut.



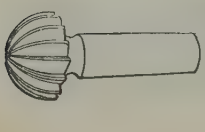
Gear Stocking Cutter—The object of stocking cutters is to rough out the teeth in gears, leaving a smaller amount of metal to be removed by the finishing cutter. They increase the accuracy with which gears may be cut, and save the finishing cutter as well.



Hob—A form of milling cutter with teeth spirally arranged like a thread on a screw and with flutes to give cutting edges as indicated. Used for cutting the teeth of worm, spur, helical or herringbone gears. Hobs are formed and backed off so that the faces of the teeth may be ground without changing the shape.



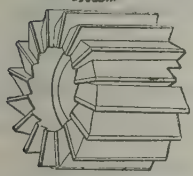
Inserted Tooth Cutter—Inserted tooth cutters have various devices for holding the blades in position in the bodies. Inserted tooth construction is generally recommended for cutters 6 inches or larger in diameter.



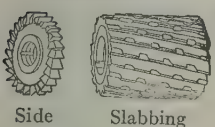
Rose Cutter—The hemispherical cutter known as a rose mill is one of a large variety of forms employed for working out dies and other parts in the profiler. Cutters of this form are also used for making spherical seats for ball joints, etc.



Screw-slotting Cutter—Screw-slotting cutters have fine pitch teeth especially adapted for the slotting of screw heads and similar work. The cutters are not ground on the sides. They are made of various thicknesses corresponding to the numbers of the American Wire Gage.

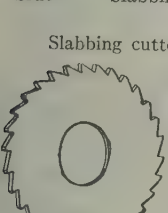


Shell-end Cutter—Shell-end mills are designed to do heavier work than that for which the regular type of end mills are suited. They are made to be used on an arbor and are secured by a screw in the end of the arbor. The end of the cutter is counter-bored to receive the head of the screw and the back end is slotted for driving as indicated. Hole is tapered $\frac{1}{8}$ inch per foot.

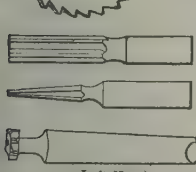


Side, or Straddle, and Slabbing Cutters—Side cutters like that to the left, cut on the periphery and sides, are suitable for milling slots and when used in pairs are called straddle mills. May be packed out to mill any desired width of slot or opposite faces of a piece of any thickness.

Slabbing cutters are frequently made with nicked teeth to break up the chip and so give an easier cut than would be possible with a plain tooth.



Slitting Saw, Metal—Metal slitting saws are thin milling cutters. The sides are finished true by grinding, and a little thicker at the outside edge than near the center, for proper clearance. Coarse teeth are best adapted for brass work and deep slots and fine teeth for cutting thin metal.



Straight-shank Cutter—Straight-shank cutters of small size are extensively used in profilers and vertical millers for die sinking, profiling, routing, etc. They are held in spring chucks or collets.

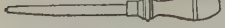
T-slot Cutter—Slots for bolts in miller and other tables are milled with T-slot cutters. They are made to standard dimensions to suit bolts of various sizes. The narrow part of the slot is first milled in the casting, then the bottom portion is widened out with the T-slot cutter.

D

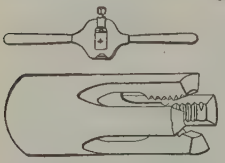
Derrick—Structure consisting of a fixed upright and an arm hinged at bottom, which is raised and lowered and usually swings around to handle heavy loads.

Dial Feed—A revolving disk which carries blanks to the punch and die, or to other tools.

Diamond Hand Tool—Used for dressing grinding wheels after they have been roughed out with the cheaper forms of cutters. Fixed diamonds are usually considered better than those held by hand.



Die Chasers—Threaded sections inserted in a die head for cutting bolts and screws.



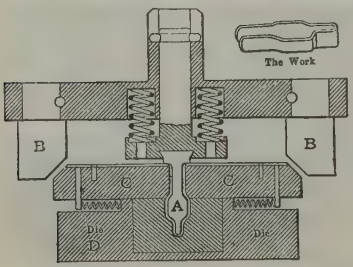
Die, Screw Plate or Stock—A frame or handle for holding a threading die. Sometimes die and handles are of one piece.

Die, Spring or Prong—Die with cutting portions in the end of prongs; can be adjusted somewhat by springing prongs together with a collar on outside.

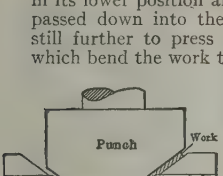
Dies, Bolt—Dies for cutting bolts. Some are solid, others adjustable. Some for hand-die stocks or plates but mostly for machine bolt cutters.

DIES, PUNCH PRESS

Bending Dies, Compound—In compound bending dies of the type shown, the work is carried down into the die by punch *A*, and held there while the beveled fingers *B* act upon the slides *C* and cause them to move forward in the top of die *D* and bend the material to the outline of the punch. Upon the up-stroke of the punch the slides *C* are pressed outwardly by their springs and the bent piece of work is removed by the punch from the die. It will be seen that the holder for punch *A*, upon which depends the interior form of the piece being bent, is not positively secured in its holder, but is instead adapted to slide up and down in its seat although prevented from turning by a small pin at the upper end of the shank which is engaged by a slot in the punch carrier. The springs shown above the punch proper tend to hold the punch

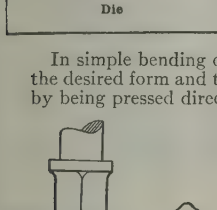


in its lower position and at the same time after the punch has passed down into the die allow the punch carrier to descend still further to press fingers *B* into operation against slides *C* which bend the work to the outline of the punch.

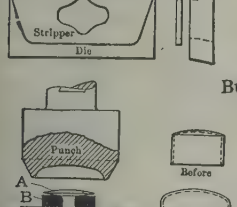


Bending Dies, Plain—Simple bending dies are made with the upper face of the die and the bottom of the punch shaped to conform to the bend it is desired to give the blank. A common type is shown in the engraving.

In simple bending dies the upper face of the die is cut out to the desired form and the piece of work formed to required shape by being pressed directly down into the die by the punch.



Blanking Dies—Blanking dies are about the most commonly used of all the varieties of press tools. A simple form of die is seen in the illustration. The strip of sheet metal is fed under the stripper and is prevented by that member from lifting with the punch upon the up-stroke, following the punching out of the blank. Where several punches are combined in one hole for blanking as many pieces simultaneously, they are known as multiple blanking tools.



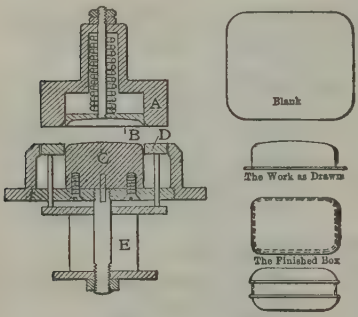
Bulging Dies—The "before and after" sketches show the character of the work handled in bulging dies. The shell after being drawn up straight is placed over mushroom plunger *A* in the bulging die, and when the punch descends the rubber disk *B* is forced out, expanding the shell into the curved chamber formed by the punch and die. Upon the punch ascending, the rubber returns to its original form and the expanded work is then removed.

Burnishing Dies—Burnishing dies are made a little smaller at the bottom than at the top and when the work is forced down through the die, the edge of the piece is given a very high finish making polishing and hand-finishing operations unnecessary. The burnishing process also forms a very accurate method of sizing work.

Coining Dies—Coining dies are operated in very powerful presses of the embossing type similar to those used for forming designs on silverware, medals, jewelry, etc. The position of the work, the retaining collar and the dies are indicated at *A*, *B*, and *C*. In the latter section the coin is shown delivered at the top of the die.

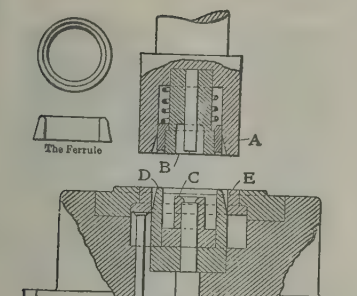


Combination Dies—Combination dies are used in single-acting presses for such work as cutting a blank and at the same stroke turning down the edge and drawing the piece into the required shape. In most cases the work is pushed out of the dies by the action of a spring. Such a set of dies is shown in the engraving, for making a box cover and body. The work is blanked by cutting punch *A*, and formed to the right shape by *B* and *C*, the former holding the piece by spring pressure to the block *C* while punch *A*, continuing to descend, draws the box to the required shape. Ring *D* acts as an ejector or shedder and is pressed down, compressing the rubber at *E* during the drawing operation, and upon the up-stroke of the punch, ascends and ejects the work from the dies.



Dies of this type, with a spring-actuated punch or die inside the regular blanking tool, are often used for simultaneously blanking and piercing, blanking and bending, etc.

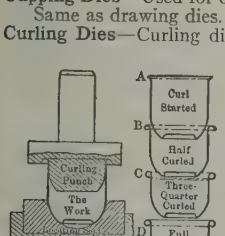
It will be noticed that the lower view in the group, showing the work at the right-hand side of the sectional illustration of the die, represents the box cover and body as they appear when assembled after the superfluous metal in the flange or "fin" has been removed in a trimming die. This fin, as left on the piece when coming from the combination die, is shown in the view immediately under the blank. A trimming die for finishing such work evenly is shown on page 912.



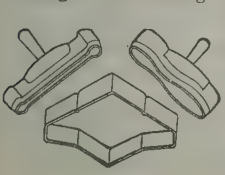
Compound Dies—Compound dies have a die in the upper punch and a punch in the lower die. The ferrule-making tools shown have a blanking and outer drawing punch *A*, with a central die *B*, to receive lower punch *C* which cuts out the center of the ferrule blank and allows the metal to be drawn down inside as well as outside of the bevel-edged member *D*. As the work is drawn down, ring *E* descends compressing rubber cushion *F* below, and upon the return movement, the ferrule is ejected from the die.

Cupping Dies—Used for drawing up a cup from a disk or planchet. Same as drawing dies.

Curling Dies—Curling dies are used for producing a curled edge around the top of a piece drawn up from sheet metal. When the top is to be stiffened by a wire ring around which the metal is curled, a wiring die is used, the construction of which is practically the same as that of the curling die. The illustration shows a curling die and the appearance of a shell at various stages during the operation of curling over the edge. The diagrams, *A*, *B*, *C*, *D*, show the progress in the curling process as the punch descends, pressing down on the edge of the straight-drawn shell.

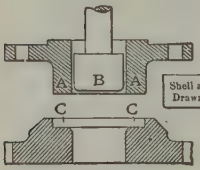


Dinking Dies—Dinking dies, or hollow cutters, although not usually classed with regular dies, are used so commonly as to entitle them to be listed in that class. They are adapted to punching out all sorts of shapes from leather, cloth, or paper. The edges of the dies (a few specimens of which are shown in the engraving) are usually beveled about 20 degrees outside. Where made for press use, the handle is omitted. As a surface

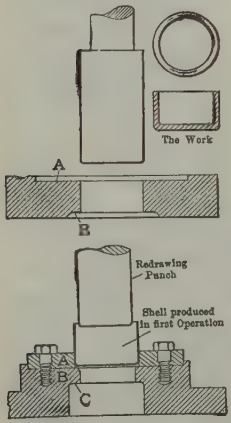


for the cutting edge of the die to strike on, a block is built up of seasoned rock maple, set endwise of the grain.

Double Action Dies—This type of die is used in a press which has a double acting ram; that is, there are two slides, one inside the other, which have different strokes. To the outer slide is fastened the combined cutting punch and blank holder *A*, which is operated slightly in advance of the drawing punch *B* actuated by the inner slide. The blank upon being cut from the stock by *A*, drops into the top of the die at *C* and is kept under pressure by the flat end of cutting punch *A* to prevent its wrinking, while punch *B* continues downward drawing the metal from between the pressure surfaces and into the shape required.

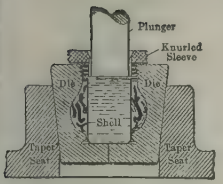


Drawing Dies, Plain—Dies of the type shown can be used for shallow drawing only, as there is no pressure on the blank to prevent its wrinkling when forced down into the die by the punch. The blank fits the recess *A* in the upper face of the die and the die itself which is slightly tapering is made the diameter of the punch plus twice the thickness of the wall required for the shell. The bottom edge *B* of the die strips the shell from the punch when the latter ascends.



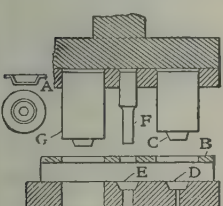
Re-drawing dies are used for drawing out a shell or cup already formed from the sheet metal. In the illustration, a shell ready for re-drawing is shown in position in the dies, which need little explanation. The work is located in the upper plate *A*, and, after being forced through the die *B*, is stripped from the punch by edge *C*. Ordinarily, a shell which is to be given considerable elongation, is passed through a number of redrawing dies.

Re-drawing dies are sometimes referred to as reducing dies, although the latter, as explained under the proper heading on page 910, are used for drawing down the end of a shell only, as in the case of a cartridge shell, which is made with a neck somewhat smaller in diameter than the body.

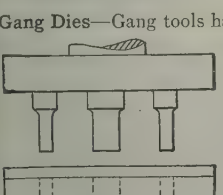


Fluid Dies—Water or fluid dies are used for forming artistic hollow ware of silver, and other soft metals, in exact reproduction of chased work. The die as shown is a hinged mold cast from carved models and finished with all details clean and sharp. The shell to be worked is filled with liquid and enclosed in the die and a plunger in the press ram then descends and causes the fluid to force the metal out into the design in the die.

Follow Dies -Follow tools consist of two or more punches and dies in one punch holder and die body, these being arranged in tandem fashion so that after the first operation the stock is fed to the next point and a second operation performed; and so on. In the die shown, which is for making piece *A*, the strip of metal is first entered beneath stripper *B* far enough to allow the first shell to be drawn at the first stroke by punch *C* and die *D*. The metal is then moved along one space and the shell drawn at the first stroke is centered and located within the locating portion of piercing die *E*. At the next stroke the hole in the center is pierced with punch *F*, and a second shell drawn in the stock by punch and die *C* and *D*. The stock is then fed forward another space and the blanking punch *G* cuts out the piece from the metal. At the same stroke a third piece is being formed on the end of the stock and a second hole pierced. Thus three operations are carried on simultaneously.



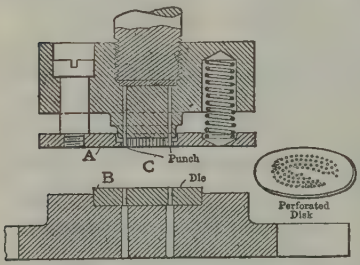
Gang Dies—Gang tools have two or more punches and dies in one holder for making as many openings in a blank at one stroke of the press. Sometimes dies which perform a number of operations on a piece which is fed along successively under one punch after another are called "gang" dies; strictly speaking, however, such tools are "follow" dies. Where a large number of punches are combined they are called a multiple punch, or if they are of quite small diameter for piercing are sometimes known as perforating punches.



Heading Dies—Heading dies strike up the heads on cartridges and other shells, and are generally operated in a horizontal heading machine.

Index Dies—For certain classes of work, such as notching the edges of large disks or armature punchings, an index die is sometimes used consisting of a rotary index plate adapted to carry the work, step by step, past the punches which cut out one notch or a series of notches at each stroke of the press.

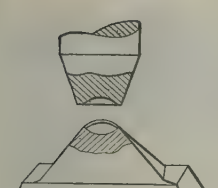
Perforating Dies—Perforating tools consist of a number of piercing tools in one set of dies and may be called also multiple piercing tools. In the example shown, which punches a large number of holes in a disk, the work is held by the spring-controlled pressure-pad *A* against the face of the die *B* while the punches at *C* are forced down through the sheet metal. In this case the punches are easily replaced when broken, by unscrewing the holder from the shank and slipping the small punch out from the back.



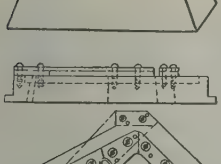
Piercing Dies—Piercing tools are used for punching small holes through sheet metal. Where arranged for punching a large number of holes simultaneously they are often called perforating dies.

Piercing Dies, Compound—Compound piercing tools have, in addition to the regular punches carried by the holder in the ram, a set of horizontal punches for making holes through the sides of the work. These side punches are operated by slides moved inward by wedge-shaped fingers, the arrangement being the same as in the case of the compound bending dies, an illustration of which is given under that head.

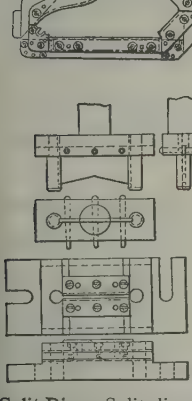
Reducing Dies—Reducing dies are re-drawing dies for reducing a portion of the shell only, whereas the regular re-drawing die reduces the whole length. Reducing dies for cartridge shells form the familiar "bottle neck" shell now so commonly manufactured, with a large body for the powder and a smaller neck into which the bullet is secured. In dial feed presses ordinarily employed for cartridge-making operations, two or more reducing dies are often used for shaping the neck of the shell to the required dimensions, each die operating in turn upon the shell as it is carried around step by step under the press tools by the intermittent rotary movement of the feeding dial.



Riveting Dies—Riveting dies for the punch press are provided with cavities in the working faces to suit the shape of the head it is desired to produce on the ends of the rivets.



Sectional Dies—Frequently dies of complicated outline are built up in sections to enable them to be more easily constructed and kept in order. This form is resorted to often in the case of large dies where a break at one point would mean considerable expense for a new die. Also the difficulties of hardening are reduced with the sectional construction. As shown, the various parts are secured to a common base or holder.



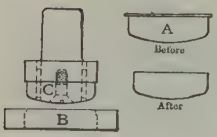
Shearing Dies—Shearing dies are used for cutting-off operations, and are frequently combined with other press tools so that after certain operations on a piece it can be severed from the end of the stock. The shearing tools in the engraving are arranged for simply cutting up stock into pieces of the required length and the punch itself is of the inserted type secured by pins in its holder.

Split Dies—Split dies form one type of sectional die—the simplest; they are made in halves to facilitate working out to shape, hardening, and economical maintenance.

Sub-press Dies—A sub-press and its tools are represented on the following page. Such tools are used for small parts which have to be made accurately and are very common in watch and typewriter shops and similar places. The tools are held positively in line in this press and as a result their efficiency is maintained indefinitely. The press is slipped bodily into the regular power press with the base clamped to the press bed and the neck of the sub-press plunger connected with the ram of the press.

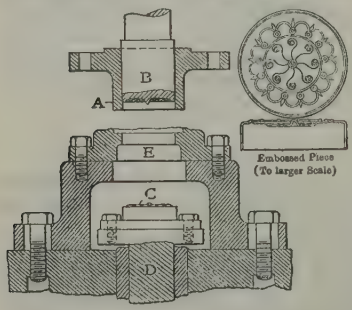
Swaging Dies—Swaging operations are resorted to where it is desired to shape up or round over the edges of work already blanked out. Thus in watch wheel work the arms and inside edges of the rims are sometimes swaged to a nicely rounded form subsequently to the blanking out of the wheel in the sub-press. Swaging dies for such work are of course made with shallow impressions which correspond to a split mold between the two halves of which the blank is properly shaped.

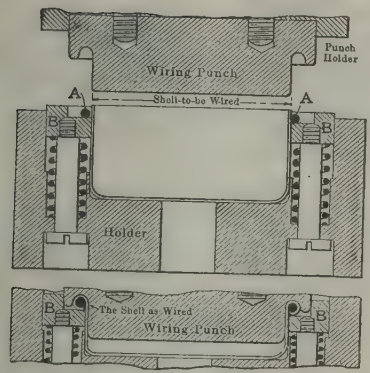
Bullet swaging dies receive the slug as it comes from the bullet mold and shape the end to the required cone point.



Trimming Dies—Trimming dies remove the superfluous metal left around the edges or ends of various classes of drawn and formed work. In the case shown, the box body *A* has been drawn up and a fin left all the way round; this is dropped into the trimming die *B* and the punch *C* in carrying it through the die trims the edge off evenly, as indicated. Work of the nature shown in this illustration is blanked, drawn up and formed ready for trimming, by means of combination tools, a typical example of which will be found under the combination die heading on page 906. The box body illustrated here as it appears before and after trimming is shown in connection with the combination dies as it appears in the blank, after it is formed, and after assembling with its cover.

Triple-action Dies—These dies are used in triple-acting presses, where in addition to the double-action slides which take the place of the regular single-acting ram, there is also a third slide or plunger which operates under the table or die bed. Thus a piece like that shown, which has to be blanked, drawn and embossed, is operated upon from above by the cutting and drawing punches *A* and *B*, and upon the latter carrying the drawn work down to the face of the embossing die *C*, that die is forced upward by the plunger *D* beneath and gives the piece the desired impression. On the up-stroke of the punch the work is stripped from it by edge *E* and falls out of the press.





Wiring Dies—Wiring dies are much the same in construction as plain curling dies. In the engraving, the wire ring is shown at *A* around the top of the shell to be wired and in a channel at the top of the spring-supported ring *B*. As indicated in the lower illustration, the punch, as it descends, depresses the ring *B* and curls the edge of the shell around the wire ring *A*.

Disks, Reference—Accurate disks of standard dimensions for setting calipers and measuring with. Usually of hardened steel.

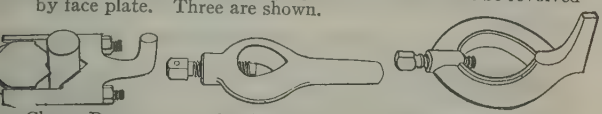


Divider, Spring—The spring tends to force the points apart and adjustments are made by the knurled nut on the screw.

Doctor—Local term for adjuster or adapter so that chucks from one lathe can be used on another. Sometimes used in the same way as the term "dutchman."

Dog—Name given to any projecting piece which strikes and moves some other part, as the reversing dogs or stops on a planer or milling machine. Sometimes applied to the pawl of a ratchet.

Dog, Lathe—A device for clamping work so that it can be revolved by face plate. Three are shown.

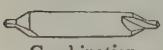


Clamp Dog Straight Tail Bent Tail

Drift—A tool for cutting out the sides of an opening while driven through with a hammer. Similar to a broach. Term sometimes applied to a taper pin for forcing holes into alignment, as in boiler work.

DRILLS


Drill


Combination

Center Drill—The short drills used for centering shafts before facing and turning are called center drills. The drill and reamer or countersink for the 60-degree center hole, when combined as shown, allow the centering to be done more readily than when separate tolls are used.

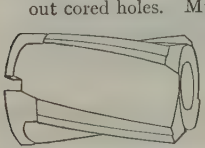
Core Drill—The core drill is a hollow tool which cuts out a core instead of removing the metal in the form of chips. Such drills are generally used to procure a core from the center of castings or forgings for the determination of the tensile strength or other physical properties of the metal.



Gun-barrel Drill—Gun-barrel drills are run at high speed and under very light feed, oil under heavy pressure being forced through a hole in the drill to clear the chips and cool the cutting point and work. The drill itself is short and fastened to a shank of suitable length.

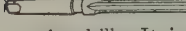


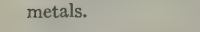
Hog-nose Drill—More like a boring tool. Mostly used for boring out cored holes. Must be very stiff to be effective.



Shell Drill—Shell drills are fitted to a taper shank and used for chucking out cored holes and enlarging holes drilled with a two-flute twist drill. The angle of the spiral lips is about 15 degrees.

Straight-flute Drill—The straight-flute, or "Farmer" drill as it is frequently called after its inventor, does not clear itself as well as the twist drill does, but is stiffer and does not "run" or follow blow-holes or soft spots as readily as the twist drill. It is also better for drilling brass and other soft metals.

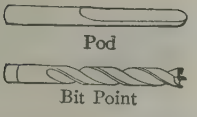

Three Groove


Four Groove

Three- and Four-groove Drills—Where large holes are to be made in solid stock it is advisable to use a three- or four-groove drill after running the required two-flute drill through the piece. These drills will enlarge the hole to the size required and are also useful in boring out cored holes in castings

Twist Drill—Usually made with two flutes, or grooves, running around the body. This furnishes cutting edges and the chips follow the flutes out of the hole being drilled.

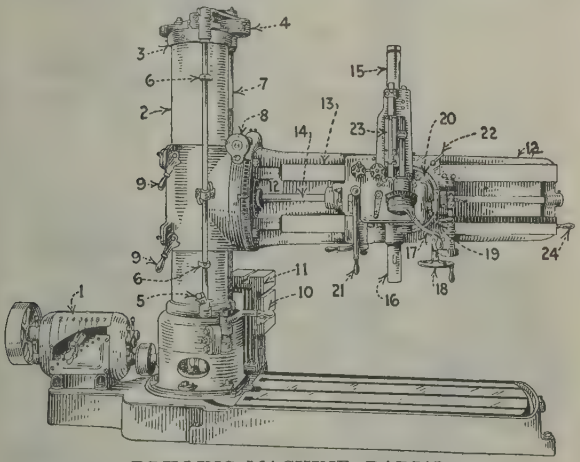




Wood Drill (Bit)—Bits for wood drilling are made in various forms. The pod drill is cut out hollow at the working end; the double-flute spiral drill has a regular bit point; the single-flute drill is full diameter for a short distance only and is cleared the rest of the length as indicated.

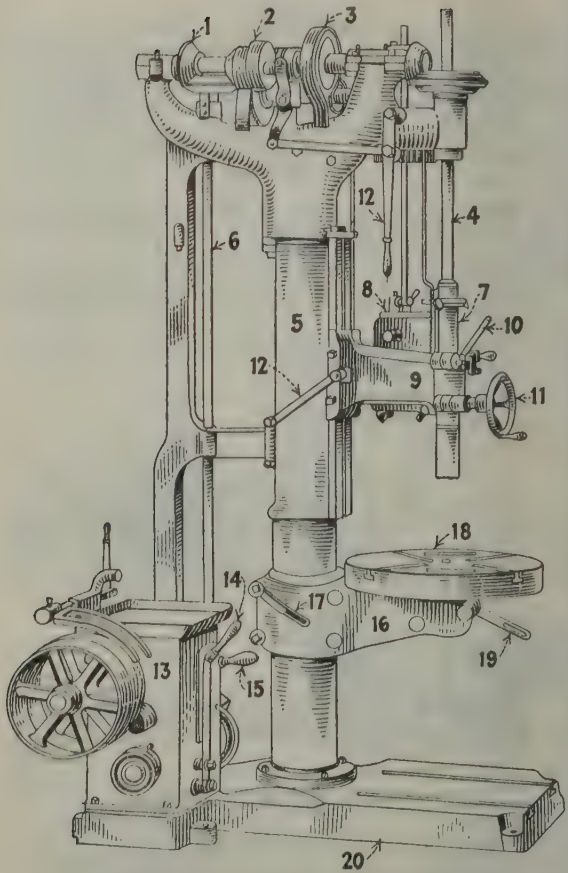
Drill, Chain—Device to be used in connection with a brace or breast drill in many places where it is not convenient to bring a ratchet drill into use.

Drill Speeder—Device which goes on drill spindle and gears up the speed of drills so that small drills can be used economically on large drill presses.



DRILLING MACHINE, RADIAL

1. Speed box.
2. Column.
3. Column cap.
4. Elevating gearing.
5. Elevating control.
6. Elevating stops.
7. Elevating screw.
8. Arm worm box.
9. Arm clamps on column.
10. Column clamp in base.
11. Table.
12. Arm.
13. Arm way.
14. Drive shaft for head.
15. Spindle sleeve.
16. Spindle.
17. Quick spindle adjustment.
18. Hand wheel for moving head on arm.
19. Hand feed wheel.
20. Swivel gear for head.
21. Spindle control lever.
22. Head clamp on arm.
23. Feed depth gage.
24. Arm handle.



DRILLING MACHINE, VERTICAL

1. Bevel driving gears.
2. Friction clutch.
3. Back gears.
4. Spindle.
5. Column.
6. Drive shaft.
7. Spindle sleeve.
8. Feed box.
9. Head.
10. Quick-return lever.
11. Hand feed wheel.
12. Head clamp.
13. Speed box.
14. Starting lever.
15. Tumbler gear lever.
16. Table arm.
17. Table arm clamp.
18. Table.
19. Table clamp.
20. Base.

Dutchman—Local term for a wedge or liner to make a piece fit. Used to make a poor job usable. A round key or pin fitting endwise in a hole drilled half in a shaft and half in the piece to be attached thereto.

E

Ejector—An ejector on punch press work is a ring, collar or disk actuated by spring pressure or by pressure of a rubber disk, to remove blanks from the interior of compound and other dies. It is often called a shedder.

End Measuring Rod—Arranged for internal measurements similar to the internal cylindrical gages.

Extractor, Oil—Machine for extracting oil from iron and metal chips. Revolves rapidly and throws out the oil by centrifugal force.

F

Face Plate—The plate or disk which screws on the nose of a lathe or other machine spindle and drives or carries work to be turned or bored. Sometimes applied to table of vertical boring mill.

Feather—A sliding key—sometimes called a spline. Used to prevent a pulley, gear or other part from turning on the shaft but allows it to move lengthwise as in the feed shaft used on most lathes and other tools. The feather is nearly always fastened to the sliding piece.

Filing Machine—Runs a file by power, usually vertically. Useful in many kinds of small work.

Fin—The thin edge or mark left by the parting of a mold or die. In drop forge work this is called the "flash."

Flute—Shop name for a groove. Applied to taps, reamers, drills and other tools.

Flywheel—Heavy wheel for steadying motion of machinery. On an engine it carries the crank past the center and produces a uniform rotation.

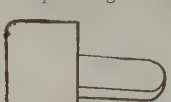
Foot Stock—The tail stock or tail block of a lathe, grinder, etc.

Force—A master punch which is used under a powerful press to form an impression in a die. Forces are commonly employed in the making of coining and other embossing dies. A similar tool used by jewelers is called a "hub." It is sometimes referred to as a "hob."

Forge—Open fireplace for heating metals for welding, forging, etc. Has forced draft by fan or bellows.

Forging Press—Heavy machine for shaping metal by forcing into dies by a steady pressure instead of a sudden blow as in drop forging. Similar to a bulldozer.

Fuller—Blacksmith's tool something like a hammer, having a roun nose for spreading or fulling the iron under hammer blowers.



Anvil Fuller

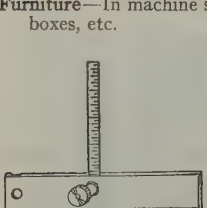


Hand Fuller



Furnace, Muffle—Furnace for heatin steel to harden, in which the flame do not come in contact with the metals

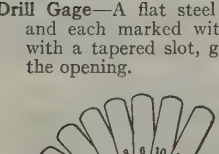
Furniture—In machine shops applies to tool racks, lathe pans, to boxes, etc.



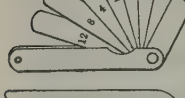
GAGES

Depth Gage—A tool for measuring th depth of holes or recesses. The bod is placed across the hole while the ru is slipped down into the hole to b measured. In many cases the rod simply a wire and not graduated.

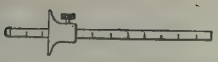
Drill Gage—A flat steel plate drilled with different-sized hol and each marked with correct size or number. Or a pla with a tapered slot, graduated to show size of drill placed i the opening.



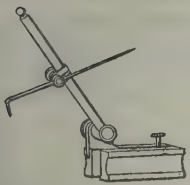
Feeler or Thickness Gage—Blades different thicknesses, usually varyin by thousandths of an inch, so tha slight variations can be felt measured.



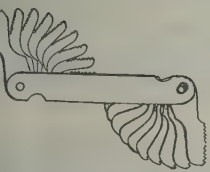
Gear-tooth Depth Gage—A gage fo measuring the depth of gear teet Requires a different gage for each pitc



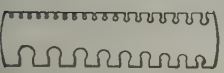
Scratch Gage—For scratching a line at a given distance from one side of a piece. Adjustable for different lengths.



Surface Gage—A tool for gaging the height between a flat surface, such as a planer table or a surface plate, and some point on the work. This can then be transferred to any other point.



Thread Gage—Tool with a number of blades, each having the same number of notches per inch as the thread it represents. Made for different kinds of threads and in various forms.



Wire Gage—Gage for measuring sizes of wire. The wire fits between the sides of the opening, not in the holes. Sometimes made in the form of a circular disk.

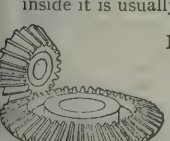


Gang Tool—A holder with a number of tools, generally used in the planer but sometimes in the lathe. Each tool cuts a little deeper than the one ahead of it.

GEARS

Angular Gears—Sometimes applied to bevel gears and also to spur gears with helical or skew teeth. See those terms.

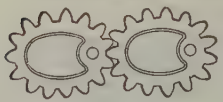
Annular Gear—Toothed ring for use in universal chucks and similar places. Teeth can be on any of the four faces, although when inside it is usually called an internal gear.



Bevel Gears—Gears cut on conical surfaces to transmit power with shafts at an angle to each other When made for shafts at right angles and with both gears of the same size are often called "miter" gears. Teeth may be either straight, skew or herring bone.

Crown Gear—A gear with teeth on the side of rim. Used before facilities for cutting bevel gears existed. Seldom found now.

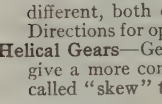
Differential Gearing—Where two gears, side by side but on differ-
ent shafts, one having a few less teeth than the other, mesh
into the same gear, each driving its shaft at a different rate
There is usually only one or two teeth difference in the two gears



Elliptical or Eccentric Gears—Gears
in which the shaft is not in the center
May be of almost any shape, oval
heart shaped, etc. Printing presses
usually have good examples of this.

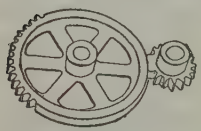
Gear Shaping Machines—The cutting of spur gears by the shaping
method is confined to the Fellows and Maag machines. The
former uses a rotary cutter that is virtually a gear while the
latter uses a straight cutter that is equivalent to a section of a
rack. While the machines and methods of indexing are quite
different, both cut the teeth by the shaping or planing process
Directions for operating are given by the makers.

Helical Gears—Gears having teeth at an angle across the face to
give a more constant pull. Also give side thrust. Sometimes
called "skew" teeth.

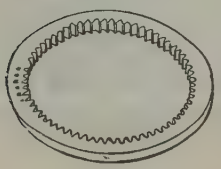


Herringbone Gears—Gears having teeth cu
at a double angle. Made by putting tw
helical or "skew"-tooth gears together
Does away with side or end thrust.

Hobbing Gears—In cutting gears by the hobbing process it is nec
essary that both the hob and the gear blank revolve in proper
relation to each other. The spindle carrying the hob must b
set to the right angle to give the gear tooth desired. For cutting
spur gears, the thread of the hob must be parallel with the axi
of the gear. For cutting helical gears, the thread of the hob
must be set parallel with the angle of the gear teeth. Then th
right gearing must be selected to rotate the hob and work th
spindles in the correct relation. Directions for doing this a
given by the makers of hobbing machines.



Intermittent Gears—Gears where t
teeth are not continuous but have pla
surfaces between. On the driven ge
these plain surfaces are concave to
the plain surface of the driver, and t
driven wheel is stationary while t
plain surfaces are in contact.



Internal Gears—Gears having teeth
the inside of a ring or shell.

Module or Metric Gears—French system of making gears with metric measurement. Pitch diameter in millimeters divided by the number of teeth in the gear.

Pin Gear—Gear with teeth formed by pins such as the old lantern pinion. Also formed by short projecting pins or knobs and only used now in some feeding devices.

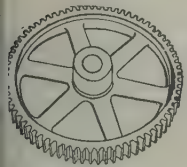
Planetary Gears—Gears mounted so as to run around a central gear, which may be either external or internal as in a Ford transmission.

Quill Gears—Gears or pinions cut on a quill or sleeve.



Spiral Gears—Spur gears with spiral teeth which run together at an angle and do the work of bevel gears.

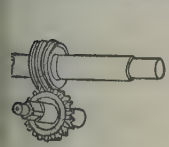
Spiral Bevel Gears—Spiral, or curved tooth bevel gears are cut with a cutter head of the trepanning type on a Gleason machine. The methods of setting the work and cutters, and of gearing the machine, are given by the makers of the machine.

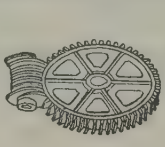


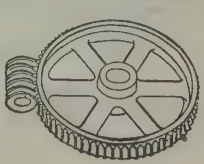
Spur Gears—Wheels or cylinders whose shafts are parallel, having teeth across the face. Teeth can be straight, helical or skew, or herringbone.

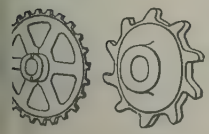
Staggered Tooth Gears—Made up of two or more straight-tooth spur gears, teeth set so that teeth and spaces break joints. Seldom used now.

Worm Gears—Gears with teeth cut on angle to be driven by a worm. Teeth are usually cut out with a hob to fit the worm.



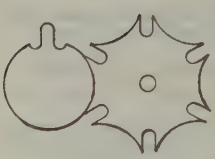






A B

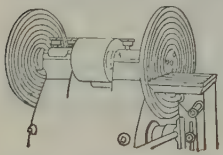
Sprocket Gears—Toothed wheels for chain driving. *A* is the regular and *B* is a hook tooth for running one way only.



Geneva Motion—A device which gives a positive but intermittent motion to the driven wheel but prevents its moving in either direction without the driver. The driver may have one tooth as shown or a number if desired. Also made so as to prevent a complete revolution of the driven wheel.

Gib—A piece located alongside a sliding member to take up wear.

Gland—A cylindrical piece enveloping a stem and used in a stuffing box to make a tight joint.



Grinder, Disk—A grinding machine having steel disks which are covered with abrasive cloth. Some disks have spiral grooves to give cushions under the abrasive cloth.

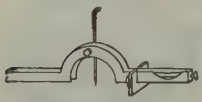
Grinder-wheel Dresser—A tool consisting of pointed or corrugated disks of hard metal which really break or pry off small particles of the grinding wheel when held against its rapidly revolving surface. Small abrasive wheels are also used.



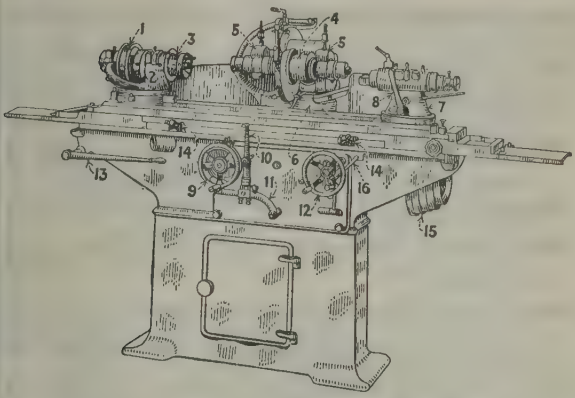
Gripe—Local name for machine clamp.

Ground Joint—A joint finished by grinding the two parts together with emery and oil or other abrasives.

Gudgeon—Local name for a trunnion or bearing which projects from a piece, such as a cannon.



Guide Liner—A tool for use in locomotive work for lining up guides and crossheads.

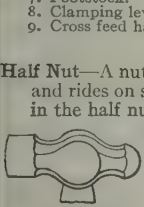


UNIVERSAL GRINDING MACHINE

1. Live spindle driving pulley.
2. Headstock.
3. Dead center pulley.
4. Wheel driving pulley.
5. Spindle-box.
6. Wheel stand platen.
7. Footstock.
8. Clamping lever.
9. Cross feed hand wheel.
10. Reversing lever.
11. Feed roll lever.
12. Table hand wheel.
13. Control lever.
14. Table dogs.
15. Feed driving cone.
16. Table hand wheel throw-out lever.

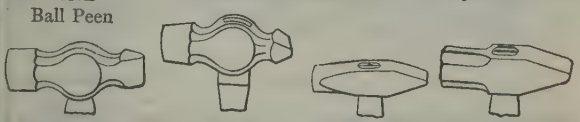
H

Half Nut—A nut which is split lengthwise. Sometimes half is used and rides on screw; in others both halves clamp around screw as in the half nut of a lathe carriage.

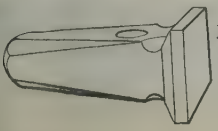


Hammer—The common types of machinists' hammers are the ball peen, straight peen and cross peen, as shown. The so-called engineers' and the riveting hammers have cross peens.

Ball Peen



Straight Peen Cross Peen Riveting Engineers



Hammer, Blacksmiths' Flatter—A flat-faced hammer used to smooth the surfaces of forgings. Is held on the work and struck by a helper with a sledge.

Hammer, Bumping or Horning—For closing seams on large cans buckets, etc.

Hammer, Drop—Hammer head or "monkey" or "drop" is raised by hand or power and falls by gravity. Sometimes raised by a board attached to top of hammer head and running between pulleys. Others use a belt.

Hammer, Helve—Power hammer in which there is an arm pivoted in the center and power applied at the back end while the hammer is at the other and strikes the work on an anvil.

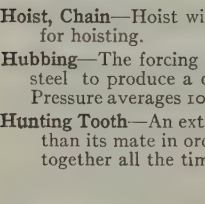
Hammer, Lever Trip—Trips the hammer by a cam or lever and allows it to fall.

Hammer, Spring—Comparatively small hammer giving a great variety in the force of blow. This is controlled by pressure of foot on lever.

Hand Wheels, Clutched—Hand wheels connected to shaft by a clutch which can be thrown out by a knob or otherwise so that accidental movement of wheel will not disturb setting. Used on milling machines and similar places.

Hanger, Drop—Shaft hanger to be fastened to ceiling with bearing held in lower end.

Hanger, Post—Shafting hanger for fastening to posts or other vertical structures.



Hardie—Blacksmith's cutting chisel which fits a hole in the anvil and forms the lower tool in cutting off work.

Hoist, Chain—Hoist with chain passing through pulley block used for hoisting.

Hubbing—The forcing of a hardened die or "hub" into cold, soft steel to produce a die or mold. A depth of $\frac{1}{2}$ in. is common. Pressure averages 100 tons to the sq. in. of area.

Hunting Tooth—An extra tooth in a wheel to give it one more tooth than its mate in order to prevent the same teeth from meshing together all the time. Seldom used now.

I

Indexing, Compound—Indexing by combination of two settings of index, either by adding or subtracting.

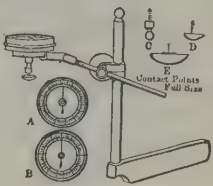
Indexing, Differential—Indexing with the index plate geared to the spindle, thus giving a differential motion that allows the indexing to be done with one circle of holes and with the index crank turned in the same direction, as in plain indexing.

Indexing, Direct—Indexing work by direct use of dividing head on milling machine.

Indicator, Lathe Test—Instrument with multiplying levers which shows slight variations in the truth of revolving work. Used for setting work in lathe or on face plate.

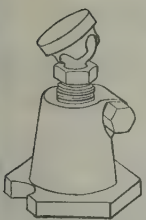


Plain Indicator



Dial Indicator

J



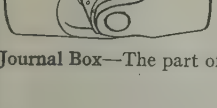
Jack, Hydraulic—Device for raising weight or exerting pressure by pumping oil or other liquid under a piston or ram.

Jack, Leveling—Small jacks (usually screw jacks) for leveling and holding work on planer beds and similar places. Practically adjustable blocking.

Jack, Screw—Device for elevating weights by means of a screw.

Jam Plates—Old name for screw plates and in many cases a true one as the thread was jammed instead of cut.

Jig, Drill—A device for holding work while drilling, having bushings through which the drill is guided so that the holes are correctly located in the piece. Milling and planing jigs (commonly called fixtures) hold work while it is machined in the milling machine and planer.



Joint, Universal—Shaft connection which allows freedom in any direction and still conveys a positive motion. Most of them can transmit power through any angle up to 45 degrees.

Journal Box—The part of a bearing in which the shaft revolves.

K

Kerf—The slot or passageway cut by a saw.

Key—The piece used to fasten any hollow object to a shaft or rod. Usually applied to fastening pulleys and flywheels to shafts; or locomotive driving wheels to their axles. Keys may be square, rectangular, round or other shape and fasten in any way. Are usually rectangular and run lengthwise of shaft.

Key, Center—A flat piece of steel, with tapered sides, for removing taper-shank drills from drill spindle or similar work.

Keyway—A groove, usually square or rectangular, in which the key is driven or in which a "feather" slides. The groove in both the shaft and piece which is to be fastened to it, or guided on it, is called a keyway.

Knurling—The rolling of depressions of various kinds into metal by the use of revolving hardened steel wheels pressed against the work. The design on the knurl will be reproduced on the work. Generally used to give a roughened holding surface for turning a nut or screw by hand.

L

Land—Space between flutes or grooves in drills, taps, reamers or other tools.

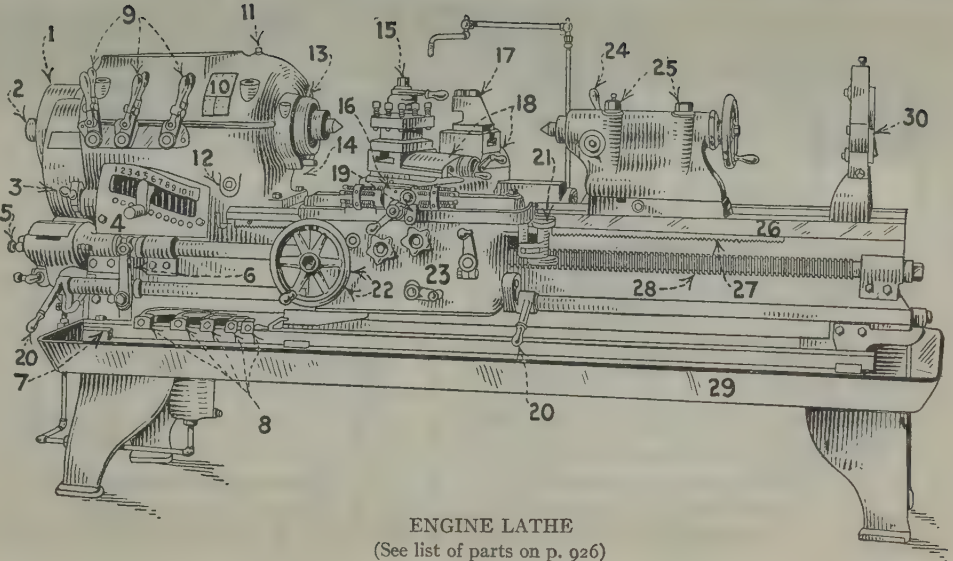
Lap—Applied to seams which lap each other. To the distance a valve must move before opening its port when valve is central on seat. To a tool usually consisting of lead, iron or copper charged with abrasive for fine grinding. See Lap, Lead.

Lap, Lead—Usually a bar of lead or covered with lead, a trifle smaller than the hole to be ground. Emery or some fine abrasive is used which gives a fine surface. Laps are sometimes held in the hand or are run in a machine and the work held stationary. Also consists at times of a lead-covered disk, revolving horizontally, which is used for grinding flat surfaces. Very similar in action to a potter's wheel.

Lathe, Engine—The ordinary form of lathe with lead screw, power feed, etc.

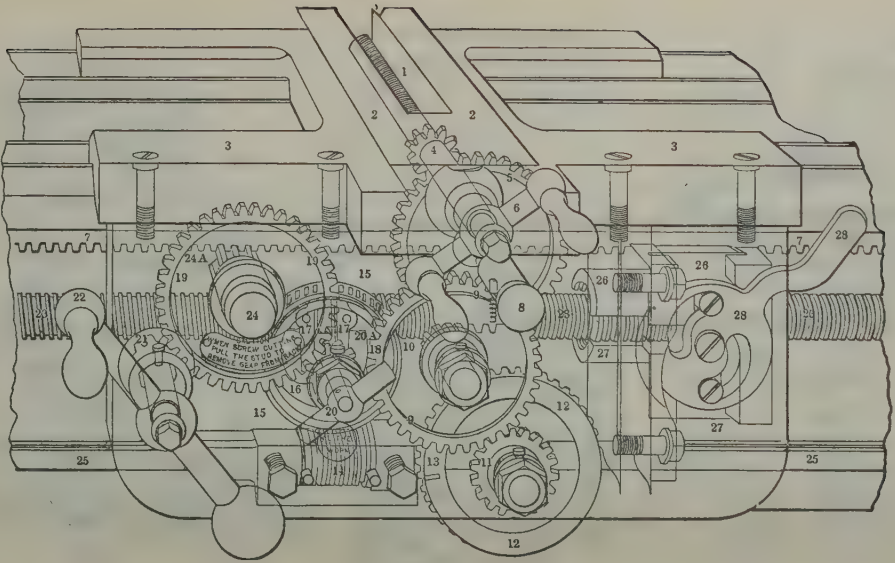
Engine Lathe Parts

1. Ball bearing driving pulley.
2. Pulley for pump.
3. Reverse plate lever.
4. Quick change gears.
5. Head screw slip gear plunger.
6. Length feed clutch.
7. Positive feed stop.
8. Adjustable feed stops.
9. Speed change levers.
10. Speed index plate.
11. Oil hole.
12. Oil drain.
13. Double nose on spindle.
14. Oil gage.
15. Four-way tool block.
16. Base to compound nest.
17. Auxiliary tool block.
18. Compound nest.
19. Diameter stops.
20. Operating levers.
21. Thread indicator.
22. Hand feed wheel.
23. Apron.
24. Tailstock spindle clamp.
25. Tailstock clamping bolts.
26. Shears or ways.
27. Rock.
28. Lead screw.
29. Chip pan.
30. Steady nest.



ENGINE LATHE

(See list of parts on p. 926)



LATHE APRON

(See list of parts on p. 929)

Lathe Apron—Parts of

1. Cross-feed screw.
2. Cross-slides.
3. Wing of saddle.
4. Cross-feed pinion.
5. Cross-feed gear.
6. Cross-feed handle.
7. Rack.
8. Power cross-feed and control.
9. Gear in train.
10. Pinion for cross-feed.
11. Main driving pinion.
12. Bevel gear.
13. Bevel pinion.
14. Feed worm.
15. Feed-worm wheel.
16. Clutch ring.
17. Clutch levers.
18. Pinion.
19. Gear in train.
20. Feed-clutch handle.
20A. Clutch spreader.
21. Hand pinion.
22. Carriage handle.
23. Lead screw.
24. Rack-pinion knob.
24A. Rack pinion.
25. Feed rod.
26. Upper-half nut.
27. Lower-half nut.
28. Half-nut cam.

NOTE.—Cross-feed is from bevel pinion 13, through gears 12, 11, 9, 10 and 4. Regular feed is through worm 14, worm wheel 15, clutch 16, pinion 18, gears 19 and 24A. Hand movement is through handle 22, pinions 21, 19 and 24A.

Lathe, Extension—So made that bed can be lengthened or shortened. When bed is made longer, there is a gap near head, increasing the swing for face-plate work.

Lathe, Fox—Brass workers' lathe having a "fox" or chasing bar for cutting threads. The bar has a "leader" which acts as a nut on a short lead screw or "hob" of the desired pitch (or half the pitch if the hob is geared down 2 to 1) and carries a tool along at the right feed for the thread. Sometimes has a turret on the back head.

Lathe, Gap—Has V-shaped gap in front of head stock to increase swing for face-plate work.

Lathe, Gun—For boring and turning cannons and rapid-fire guns.

Lathe, Ingot—For boring, turning and cutting off steel ingots.

Lathe, Precision—Bench lathe made especially for small and very accurate die, jig or model work.

Lathe, Projectile—Simply a heavy lathe for turning up projectiles. Sometimes has attachment for pointing them.

Lathe, Pulley—Especially designed for turning pulleys, can turn them crowning or straight.

Lathe, Roll Turning—For turning rolling mill, steel mill and calender rolls.

Lathe, Screw Cutting—Having lead screw and change gears for cutting threads.

Lathe, Shafting—For turning long shafts or similar work.

Lathe, Speed—A simple lathe with no mechanically actuated carriage or attachments.

Lathe, Spinning—For forming sheet metal into various hollow shapes, all circular. Done by forcing the sheet against a form of some kind (with a single, round-ended tool) while it is revolving.

Lathe, Turret—A lathe having a multiple tool holder, or turret, which revolves and takes the place of tail or foot stock. Many have automatic devices for turning turret and for feeding tools into the work.

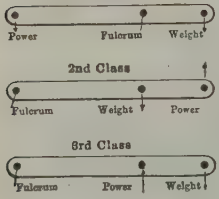
Lathe, Vertical—Name given a type of vertical boring mill on account of a side head which acts very much like a lathe carriage and does a large variety of work that would ordinarily be done on the face plate of a lathe.

Lathe, Watchmakers'—A very small precision lathe.

Lead—The advance made by one turn of a screw.

Level, Quartering—A tool for testing driving wheels to see if crank pins are set 90 degrees apart. The level has a forked end and with the angles shown. Placing this on the crank pin and lining the edge with the center of axle should bring the bubble of level in the center. If the same result is obtained on the other wheel, the crank pins are 90 degrees apart.



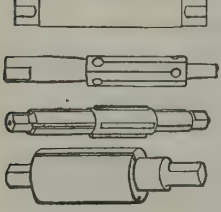


Levers—Arms pivoted or bearing on points called fulcrums. Divided into three classes as shown. First has fulcrum or bearing point between power and weight, second has weight between power and fulcrum and third has power between weight and fulcrum.

Liner—A piece for separating pieces a desired distance; also called shim.

M

Machine Tool—The name given to any machine of that class, which taken as a group, can reproduce themselves, such as the lathe, drilling machine, planer, milling machine, etc. No other class of machines can be used to build other machines, and because of this, machine tools are known as the "master tools of industry."

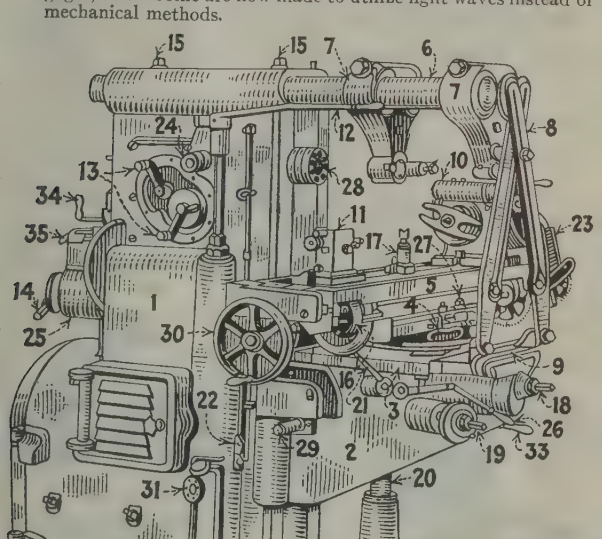


Mandrel—Shafts or bars for holding *work* to be machined. Plain mandrels, as shown at the top, have a taper of about 0.010 inch per foot and are forced into the work. There are also several types of expanding mandrels, three being shown. The second and fourth mandrels have spring sleeves on a taper bar. The third has blades sliding in tapered grooves. Mandrels should not be confused with arbors that are for holding and driving cutting tools only.

Marking Machine—A machine for stamping trade-marks, patent dates, etc., on cutlery, gun barrels, etc. Stamps are usually on rolls and rolled into work.

Master Plate—See Plate, Master.

Measuring Machine—Practically a large bench micrometer caliper of any desired form to measure work such as taps, reamers, gages, etc. Some are now made to utilize light waves instead of mechanical methods.

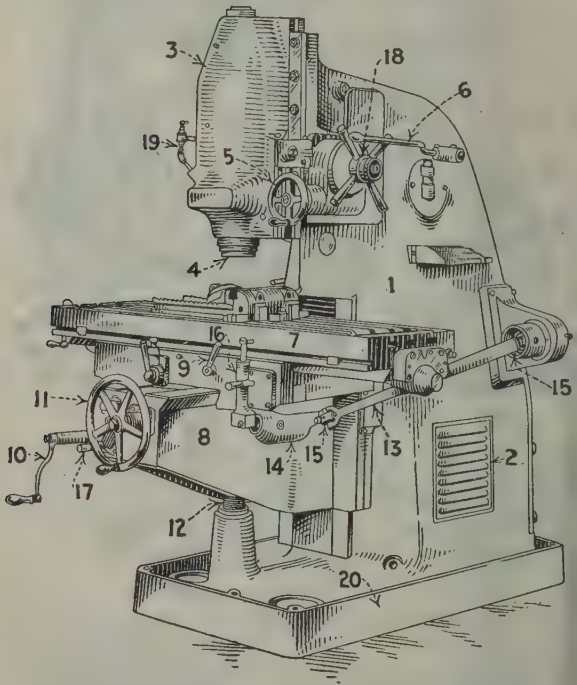


MILLING MACHINE, UNIVERSAL

1. Column.
2. Knee.
3. Saddle.
4. Universal swivel block.
5. Work table.
6. Over arm.
7. Arm bracket or arbor supports.
8. Arm braces or harness.
9. Knee clamp for braces.
10. Spiral dividing head.
11. Tailstock.
12. Starting lever.
13. Speed change lever.
14. Feed change lever.
15. Arm clamp screws.
16. Table stops.
17. Steady rest.
18. Cross feed screw.
19. Elevating shaft.
20. Elevating screw—telescopic.
21. Saddle clamp levers.
22. Vertical feed trip blocks.
23. Change gear bracket.
24. Spindle lock.
25. Feed box.
26. Cross and vertical feed handle.
27. Table trip handle.
28. Spindle collar.
29. Interlocking feed lever.
30. Table screw.
31. Oil sight gage.
32. Oil drain plug.
33. Cross and vertical feed reverse lever.
34. Primary feed selection lever.
35. Secondary feed selection lever.

Milling Machine—A machine in which the operating tool is a revolving cutter. Has table for carrying work and moving it so as to feed against cutter.

Milling Machine, Universal—Has work table and feeds so arranged that all classes of plane, circular, helical, index, or other milling may be done. Equipped with index centers, chuck, etc.



MILLING MACHINE, VERTICAL

1. Column.
2. Ventilators for motor in base.
3. Spindle head.
4. Spindle nose.
5. Worm gear head control.
6. Control lever.
7. Table.
8. Knee.
9. Saddle.
10. Hand elevation of knee.
11. Saddle feed wheel.
12. Knee elevating screw.
13. Power feed drive.
14. Feed gear box.
15. Universal joints.
16. Table control.
17. Power saddle control.
18. Direct head control.
19. Spindle oiler.
20. Base.

Milling Machine, Vertical—Differs from horizontal machine mainly in having a vertical spindle for carrying the cutter.

Miter—A bevel of 45 degrees.

N

Necking Tool—Tool for turning a groove or neck in a piece of work.

Nose—In shop work the term is applied to the business end of tools or things. The threaded end of a lathe or milling-machine spindle or the end of "hog-nose drill" or similar tool.

Nut, Cold Punched—A nut punched from flat bar stock. The hole is usually reamed to size before tapping.

Nut, Hot Pressed—A nut formed hot in a forging machine.

Nut Machine—A machine for cutting, drilling and tapping nuts from a bar or rod.

Nut Tapper—A machine for tapping hole in nuts.

Nuts—See Bolts; also pages 890 and 892.

O

Ogee—Name given to a finish or beading consisting of a reverse curve. Applied to work of any class, wood or iron.

Oval—Continuously curved but not round, as a circle which has been more or less flattened.

Overhead—A term usually applied to expenses that come from rent, taxes, interest on investment, depreciation, upkeep or maintenance, supervision, insurance and any other expenses that do not come under the head of direct labor or material. Some separate it into machine-overhead, etc.

P

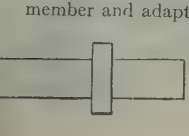
Pawl—A hinged piece which engages teeth in a gear, rack or ratchet for moving it or for arresting its motion. Sometimes used to designate a piece such as a reversing dog on a planer or milling machine.

Peening—The stretching of metal by hammering or rolling the surface. Used to compress babbitt to fit tightly in a bearing, to straighten bars by stretching the short or concave side, etc.

Pickling Castings—Dipping into acid solution to soften scale and remove sand. Solution of eight or ten parts of water to one of sulphuric acid is used for iron. For brass use five parts water to one of nitric acid.

Pickling Forgings—Putting in bath of one part sulphuric acid to twenty-five parts boiling water to remove scale. Can be done in 10 minutes. Rinse in boiling water and they will dry before rusting.

Pin, Collar—A collar pin is driven tight into a machine frame or member and adapted to carry a roll, gear, or other part at the outer end. It differs from the collar stud in not having a thread at the inner end. When drilled through the end for a cotter pin it is known as a fulcrum pin, as it is then especially suited for carrying rocker arms, etc.

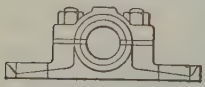


Pin, Dowel, Screw—Dowel pins are customarily made straight, or plain taper and fitted into reamed holes. When applied in such a position in a mechanism that it is impossible to remove them by driving out, they are sometimes threaded and screwed into place.

Pin, Taper—Taper pins for dowels and other purposes are regularly manufactured with a taper of $\frac{1}{4}$ inch to the foot and from $\frac{3}{4}$ to 6 inches long, the diameters at the large end of the sizes in the series ranging from about $\frac{5}{32}$ to $\frac{23}{32}$ inch. The reamers for these pins are so proportioned that each size "overlaps" the next smaller size by about $\frac{1}{2}$ inch.



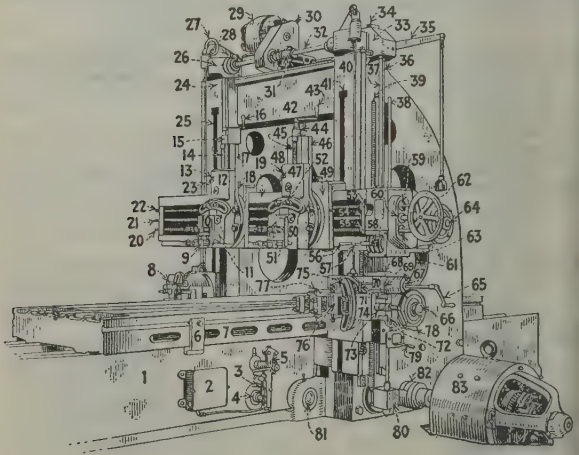
Pitch—The distance from the center of one screw thread, or gear tooth or serration of any kind to the center of the next. In screws with a single thread the pitch is the same as the lead but not otherwise.



Pillow Blocks—Low shaft bearings, resting on foundations, or floors or other supports.

Pitman—A connecting rod; term used more commonly in connection with agricultural implements.

Planchet—Blank piece of metal punched out of a sheet before being finished by further work. Such as the blanks from which coins are made.



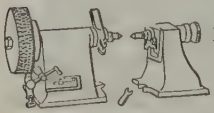
PLANER

(See list of parts on p. 935)

List of Parts of Planer

1. Bed.
2. Master switch.
3. Slotted lever.
4. Bull gear shaft.
5. Shifter lever.
6. Front dog, right hand.
7. Table.
8. Left hand side head.
9. Tool clamp.
10. Apron of left hand rail head.
11. Tool box of left hand rail head.
12. Slide of left hand head.
13. Slide clamp of left hand head.
14. Down feed screw, left hand head.
15. Graduated collar for down feed.
16. Down feed crank.
17. Harp, left hand head.
18. Saddle of left hand head.
19. Rail.
20. Cross feed screw for right hand head.
21. Down feed rod.
22. Cross feed screw for left hand head.
23. Counterweight cable for left hand side head.
24. Left hand housing.
25. Left hand rail elevating screw.
26. Rapid traverse gear case, left hand.
27. Side head counterweight sheave.
28. Centralized oiler for traverse gears.
29. Traverse motor.
30. Rail setter gear case.
31. Safety clutch for rail setter.
32. Elevating shaft.
33. Case for traverse gears, right hand.
34. Centralized oiler for traverse gears.
35. Rail setter lever.
36. Traverse control shaft.
37. Traverse drive shaft.
38. Feed drive shaft.
39. Side head screw, right hand.
40. Right hand housing.
41. Right hand rail elevating screw.
42. Top brace.
43. Down feed crank for right hand head.
44. Graduated collar for down feed, right hand head.
45. Down feed screw, right hand head.
46. Harp for right hand head.
47. Slide for right hand head.
48. Slide clamping screw for right hand head.
49. Saddle for right hand head.
50. Tool box for right hand head.
51. Apron for right hand head.
52. Tool box clamping bolts, right hand head.
53. Graduated collar for cross feed screw of left hand head.
54. Graduated collar for down feed at end of rail.
55. Graduated collar for cross feed of right hand head.
56. Traverse lever for left hand head across rail.
57. Traverse lever for slides up or down.
58. Traverse lever for right hand head across rail.
59. Ratchet feed gear for left hand head.
60. Ratchet feed gear for down feed.
61. Ratchet feed gear for right hand head.
62. Rail lock shaft.
63. Feed reverse tumbler gear.
64. Cantslip feed dial.
65. Side head crank.
66. Side head cantslip feed dial.
67. Ratchet feed gear for side head.
68. Centralized oiler for side head.
69. Clamp for saddle of right hand side head.
70. Saddle of right hand side head.
71. Clamp for side head slide.
72. Harp for side head.
73. Graduated collar for feed, side head.
74. Slide for side head.
75. Side head tool box.
76. Side head apron.
77. Self releasing plunger for side head apron.
78. Crank for in and out feed on side head.
79. Rapid traverse lever for side head.
80. Bevel gears for feed drive.
81. Shaft for second intermediate gear.
82. Flexible coupling for drive shaft.
83. Reversing motor.

Planer—A machine for producing plane surfaces on metals. The work is held on table or platen which runs back and forth under the tool which is stationary.



Planer Centers—A pair of index centers to hold work for planing. Similar to plain milling machine centers.

Planer, Open Side—A planer with only one upright or housing, supporting an overhanging arm which takes the place of the usual cross-rail. Useful in planing work too wide to go in the ordinary planer.

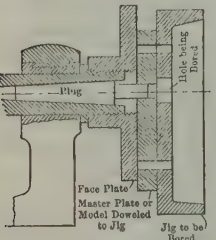
Planer, Radius—For planing parts of circles, such as links for locomotive or stationary-engine valve motion.

Planer, Rotary—Really a large milling machine in which the work is carried past a rotary cutter by the platen.

Planer, Traveling Head—Planer in which work is stationary and tool moves over it. Seldom used in U. S. A.

Planishing—The finishing of sheet metal by hammering with smooth-faced hammers or their equivalents.

Plate, Master—A steel plate serving as a model by which holes in jigs, fixtures and other tools are accurately located for boring. In the illustration the piece to be bored is shown doweled to the master plate which is mounted on the face plate of the lathe. In the master plate there are as many holes as are to be bored in the work, and the center distances are correct. The plate is located on a center plug fitting the lathe spindle, and after a given hole is bored in the work, the master plate and work are shifted and relocated with the center plug in the next hole in the plate and the corresponding hole in the work is then bored out. This is one of the most accurate methods employed by the toolmaker on precision work.



Platen—A work-holding table on miller, planer or drill.

Plumb Bob, Mercury—Plumb bob filled with mercury to secure weight in a small space.

Press, Blanking—For heavy punching or swaging.

Press, Broaching—A press for pulling or forcing broaches through holes in metal work.

Press, Cabbaging—For compressing loose sheet-metal scrap into convenient form for handling and remelting.

Press, Coining—For making metal planchets from which coins are stamped. Usually has a toggle action.

Press, Double Action—Has a telescoping ram or one ram inside the other, each driven by an independent cam so that one motion follows the other and performs two operations for each revolution of the press.

Press, Forcing—For forcing one piece into another, such as a rod brass into a locomotive connecting rod.

Press, Forging—For forging metal by subjecting it to heavy pressure between formers or dies.

Press, Horning—For closing side seams on pieced tinware.

Press, Inclinable—One that can be used in vertical or inclined position.

Press, Screw—Pressure is applied by screw.

Press, Straight-sided—Made with perfectly straight sides so as to give great strength and rigidity for heavy work.

Press, Pendulum—Foot press having a pendulum-like lever for applying power to the ram.

Profiling Machine—A milling machine in which the cutter can be made to follow outline or pattern in shaping small parts of machines. Practically a vertical milling machine.

Protractor, Bevel—Graduated semicircular protractor having a pivoted arm for measuring off angles.

Pull-pin—A means of locking or unlocking two parts of machinery. Sometimes slides gears in or out of mesh and at other times operates a sliding key which engages any desired gear of a number on stud.

Pulley, Gallow or Guide—Loose pulley mounted in movable frames to guide and tighten belts.

Pulley, Idler—A pulley running loose on a shaft and driving on machinery, merely guiding the belt. Practically same as a "loose pulley."

Pulley, Loose—Pulley running loosely on shaft doing no work. Carries belt when not driving tight (or fast, or working) pulley. Use on countershafts, planers, grinders, etc., where machine is idle part of time. Belt is then on the loose pulley, but when shifted to tight pulley, the machine starts up.

Punching—A piece cut out of sheet stock by punch and die; the same as blank.

Punch, Belt—Hollow, round or elliptical punch for cutting holes for belt lacing.

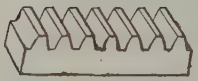
Q

Quadrant—A segment of a circle. The swinging plate carrying the change gears in the feed train at the end of the lathe.

Quick Return—A mechanism employed in various machines to give a table, ram or other member a rapid movement during the return or non-cutting stroke.

Quill—A hollow shaft which revolves on a solid shaft, carrying pulleys or clutches. When clutches are closed, the quill and shaft revolve together.

R



Rack—A strip cut with teeth so that a gear can mesh with it to convert rotary into reciprocating motion or vice versa.

Ratchet—A gear with triangular-shaped teeth adapted to be engaged by a pawl which either imparts intermittent motion to the ratchet or else locks it against backward movement when operated otherwise.



Ratchet Drill—Device for turning a drill when the handle cannot make a complete revolution. A pawl on the handle drops into a ratchet wheel on the barrel so that it can be turned one or more teeth.

Recess—A groove below the normal surface of work. On flat work a groove to allow tool to run into as a planer, or a slide to run over as a cross-head on a guide. In boring a groove inside a hole. If long it is often called a chamber.

Relief or Relieving—The removing of, or the amount removed to reduce friction back of cutting edge of a drill, reamer, tap, etc. Also applied to other than cutting tools. See Backing Off.

REAMERS

Reamer—A tool to enlarge a hole already existing, whether a cast or cored hole or one made by a drill or boring bar. Reamers are of many kinds and shape as indicated below. Usually a reamer gives the finishing touch to a hole.

Ball Reamer—Usually a fluted or rose reamer for making the receiving portion of a ball joint. It is considered advisable to space the teeth irregularly, as this tends to prevent chattering.

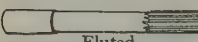
Bridge Reamer—A reamer used by boiler makers, bridge builders, ship builders, etc., has a straight body from *A* to *B* and tapered end from *B* to *C*. This reamer has a taper shank and can be used in an air drill.





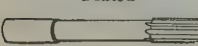
Flat

Center Reamer—Center reamers, or countersinks for centering the ends of shafts, etc., are usually made 60 degrees included angle. Combined center drill and reamer are now universally used.



Fluted

Chucking Reamer—Chucking reamers are used in turret machines. The plain, fluted type has teeth relieved the whole length; while the rose reamer cuts only on the end, as there is no peripheral clearance. Where possible, reamers used in the



Rose

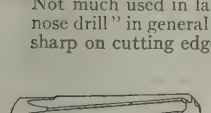
turret should be mounted in floating holders which allow the reamer to play sidewise sufficiently to line up with the hole in the work which may be so drilled or bored as not to run perfectly true prior to the reaming operation.

Chucking Reamer (Three-groove)—Spiral fluted chucking reamers with three and four grooves are employed for enlarging cored holes, etc. They are also made with oil passages through them and in this form are adapted to operating in steel.



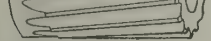
Flat Reamer—A reamer made of a flat piece of steel. Not much used except on brass work and then usually packed with wooden strips to fit the hole tightly. Flat reamers are not much used except for taper work.

Half-round Reamer—Used considerably in some classes of work, particularly in small sizes and taper work when taper is slight. Not much used in large sizes. Somewhat resembles the "hog-nose drill" in general appearance except that this is always quite sharp on cutting edge.

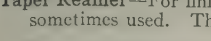


Shell Reamer—Shell reamers have taper holes to fit the end of an arbor on which they are held in the chucking machine. They are made with both straight and spiral flutes. Made with a variety of flutes. Taper hole is $\frac{1}{8}$ inch to the foot.

Taper Reamer—For finishing taper holes two or more reamers are sometimes used. The roughing reamer is often provided with nicked or stepped teeth to break up the chip. Taper reamers are also made with spiral teeth. Where the taper is slight, the spiral should be left-hand to prevent the reamer from drawing in too fast; where the taper is abrupt, the teeth, if cut with right-hand spiral, will help hold the reamer to the cut and make the operation more satisfactory.



Roughing

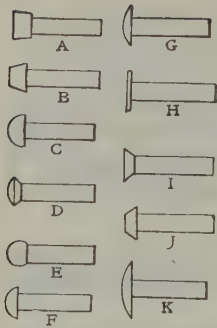


Finishing

Taper-pin Reamer—See Taper Pins.

Riffle—Name given a small file used by die sinkers and on similar work.

Rivet—A pin for holding two or more plates or pieces together. A head is formed on one end when made; the other end is upset after the rivet is put in place and draws the riveted members close together.



Rivets

A—Machine Head
B—Cone Head
C—Wheel Head
D—Oval Countersunk Head
E—Globe Head
F—Round Head
G—Truss Head
H—Flat Head
I—Countersunk Head
J—Bevel Head
K—Wagon-box Head.

Rivet Machine—For making rivets from metal rods.



Rule, Hook—Rule with a hook on the end for measuring through pulley holes and in similar places.

Rule, Keyseat—For laying out keyseats on shaft or in hubs.

Rule, Shrink—Graduated to allow for shrinkage in casting. Used by pattern makers and varies with metal to be cast.

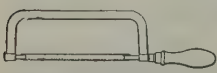
Rust Joint—A joint made by application of cast-iron turnings mixed with sal ammoniac and sulphur to cause the turnings to rust and become a solid body.

S

Sand Blast—Sand is blown by compressed air through a hose as desired. Used to clean castings, stonework, etc.

Saw, Band—Continuous metal band, toothed on one edge and guided between rolls. Mostly used on woodwork, but its use on metal work is increasing.

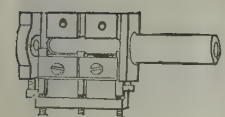
Saw, Cold—Machines for sawing metal with circular saws.



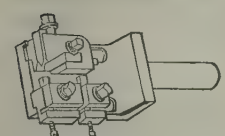
Saw, Hack—Close-toothed saw for cutting metal. Saws are held in a hand frame or in power-driven machines.

Scarf—The bevel edge formed on a piece of metal which is to be lap welded.

SCREW-MACHINE TOOLS

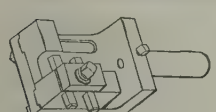


Box Tool, Bushing—The cutters in this tool are placed with edges radial to the stock and may be adjusted to turn the required diameter by the screws in the rear. The stock is supported in a bushing and must therefore be very true and accurate as to size.

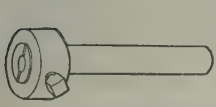


Box Tool, Finishing—The material turned in this box tool is supported by adjustable back-rest jaws, and the cutters are also adjustable in and out, as well as lengthwise, of the tool body.

Box Tool, Roughing—This tool has one or more cutters inverted over the work and with cutting edges tangent to the material.

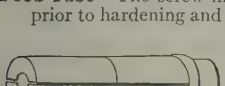


The back rest is bored out the size the screw or other piece is to be turned, and the cutter turns the end of the piece to size before it enters the back rest. Sometimes a pointing tool is inserted in the shank for finishing the end of the work.

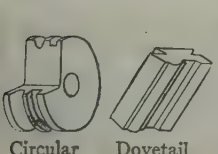


Drill Holder—The end of the drill holder is split and provided with a clamp collar by which the holder is closed on the drill.

Feed Tube—The screw-machine feed tube or feed finger is closed prior to hardening and maintains at all times a grip on the stock.



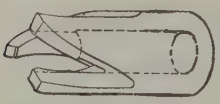
The rear end is threaded and screwed into the tube by which it is operated. It is drawn back over the stock, and when the chuck opens, is moved forward, feeding the stock the right distance for the next piece.

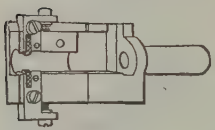


Circular Dovetail

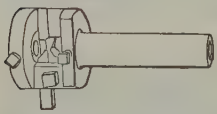
Forming Tools—Circular forming cutters are generally cut below center to give proper clearance, and the tool post is bored a corresponding amount above center to bring the tool on the center line. Dovetail cutters are made at an angle of about 10 degrees for clearance.

Hollow Mill—Usually made with three prongs or cutting edges and with a slight taper inside toward the rear. A clamp collar is used on mill like a spring-die collar, and a reasonable amount of adjustment may be obtained by this collar. Hollow mills are frequently used in place of box tools for turning work in the screw machine.



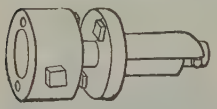


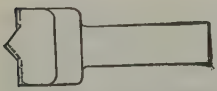
Knurling Tool—The two knurls in this box are adjustable to suit different diameters of work.



Pointing Tool—The bushing in this tool receives and supports the end of the round stock and the cutters carried in the frame form and point the end.

Revolving Die Holder—The common type of revolving die holder which is generally used with spring dies has a pair of driving pins behind the head and in the flange of the sleeve which fits into the turret hole. At the rear end of the sleeve is a cam surface which engages a pin in the shank of the head when the die is reversed. The die is run on to the work with the driving pins engaged. When the work is reversed, the cam at the rear engages the pin in the shank and holds the die from turning so that it must draw off the work.

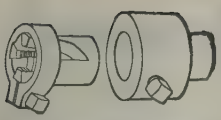




Spotting Tool—This tool spots a center in the end of the bar of stock to allow the drill to start properly, and also faces the end of the piece true. Sometimes called "centering and facing" tool. It is desirable to have the included angle of the cutting point less than that of the drill which follows it, in order that the latter may start true by cutting at the corners first.

Spring Collet—Spring collets or chucks are made to receive round, square, hexagonal or other stock worked in the screw machine. The collet is hardened and is closed in operation by being pressed into the conical cap into which it fits. When released, it springs open sufficiently to free the stock and allow it to be fed through the collet.

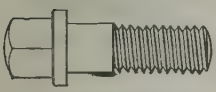




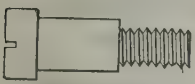
Spring Die and Extension—Spring dies or prong dies are provided with a collar at the end for adjusting and are easily sharpened by grinding in the flutes.

Screw Plates—Holders for dies for cutting threads on bolts or screws. Dies are usualiy separate but sometimes cut in the piece which forms the holder.

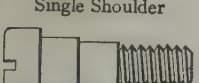
Screws—The machine screws in most common use are shown under Bolts, Nuts and Screws. A few of the less-used varieties are shown here.



Collar Screw—Collar or collar-head screws are used for much the same purposes as regular cap screws, and, in fact, are sometimes designated as "collar" cap or "collar-head" cap screws.

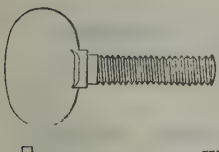


Single Shoulder



Double Shoulder

Shoulder Screw—Shoulder screws are commonly used for carrying levers and other machine parts that have to operate freely. The screw body is enough longer than the thickness of the piece pivoted thereon to allow the latter to work easily when the screw is set up tight against the bottom of the shoulder. With double shoulders two members may be mounted side by side and left free to operate independently of each other.

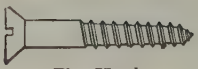


Thumb Screw—A screw with a winged or knurled head which may be operated by hand when a quick and light clamping effect is desired.

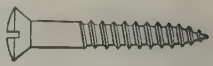


Washer-head Screw—The washer formed on this screw enables it to be used for holding pieces with large holes without applying a loose washer.

Wood Screws—Wood screws are made in an endless variety of forms, a number of which are shown on the following page. They range in size from No. 0 to No. 30 by the American Screw Company's gage and are regularly made in lengths from $\frac{1}{4}$ inch to 6 inches. Generally the thread is cut about seven-tenths of the total length of the screw. The flat-head wood screw has an included angle of head of 82 degrees.



Flat Head



Oval Head



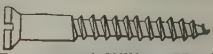
Round Head



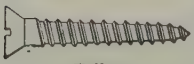
Piano Head



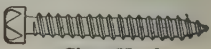
Oval Fillister Head



Countersunk Fillister Head



Felloe



Clove Head



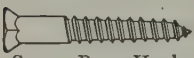
Hexagon Head



Headless



Grooved



Square Bung Head



Pinched Head



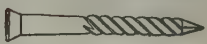
Round Bung Head



Dowel



Winged



Drive



Winged



Winged Head

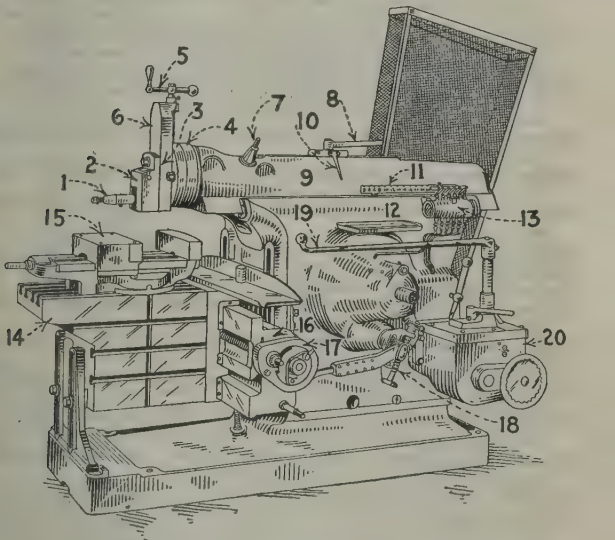
Sector—A device used on an index plate of a dividing head for indicating the number of holes to be included at each advance of the index crank in dividing circles. The sector can be opened or closed to form as large or small an arc as necessary to cover the desired number of holes for each movement of the crank.

Set—The bend to one side of the teeth of a saw.

Shaft, Flexible—Shaft made of a helical spring or of jointed parts, to transmit power in varying directions. Usually confined in a casing of fabric or of flexible tubing.

Shaft, Line—The shafting driving the machinery of a shop or section of a shop by means of pulleys and belts.

Shaper—A machine in which the work is held on table or knee while the tool held by a tool post on the moving ram moves across it. Table is adjustable for depth of cut, etc.



SHAPER

1. Tool post.
2. Clapper block.
3. Clapper box.
4. Tool head.
5. Tool head feed screw.
6. Tool slide.
7. Ram adjuster.
8. Position lever.
9. Ram.
10. Stroke indicator.
11. Stroke scale.
12. Ram guide.
13. Oiler.
14. Table.
15. Vise.
16. Saddle.
17. Cross-feed.
18. Feed adjustment.
19. Control lever.
20. Speed change box.

Shaper, Crank—A shaper in which the ram is driven by a crank motion.

Shaper, Draw Cut—The cutting stroke takes place when tool is moving toward frame of machine. This tends to draw the parts together.

Shaper, Gear—A machine for planing or shaping gear teeth by using a hardened cutter, shaped like a pinion gear as a tool, and moving it across the face of the gear.

Shaper, Geared—The ram is driven by rack and pinion with a slow cutting stroke and a quick return by shifting open and crossed belts the same as on a planer.

Shapers, Traverse or Traveling Head—The ram feeds across work, which is stationary.

Shears—Tools for cutting metals between two blades. The ways on which the lathe carriage and tail stock move are called "shears" by some, "ways" by others. They may be either V, flat or any other shape. Also a hoisting apparatus used on wharves or docks, consisting of two heavy struts like an inverted V.

Shedder—A plate or ring operated by springs or by a rubber pad to eject a blank from a compound die. It acts as an internal stripper, and is sometimes known as an ejector.

Sherardizing—The name given to a new process of dry galvanizing of any iron product.

Shifter Forks—Arms to guide belt from tight to loose pulley or vice versa, by pressing the sides.

Shim—A liner or piece to place between surfaces to secure proper adjustment.

Shrink Fit—See Calipering and Fitting.

Slip Washer—See Washer, Open.

Slotted Washer—See Washer, Open.

Slotter—A machine for planing vertical surfaces or cutting slots. The tool travels vertically.

Socket, Grip—A device for driving drills and other tools with either a straight or taper shank.

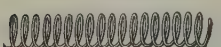
Sow or Sow-block—Local name for a chuck for holding work, such as dies. A ball chuck.

Spinning—The forming of sheet metal by rolling it against forms such as lamp bodies. Lathes are made expecially for this work.

Spline—Used in some sections in place of "key" and in others the same as "feather." See Key and Feather.

Split Nut—Nut split lengthwise so as to open for quick adjustment.

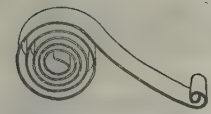
Spot or Spotting—Spotting is making a spot or surface for a locating point or to lay out from. Also used to designate place turned for steady nest support, before turning balance of a shaft.



Spring, Compression—A helical spring which tends to shorten in action.

Spring, Helical—A spring coiled lengthwise of its axis like a screw thread. Often incorrectly called a spiral spring.

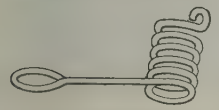
Spring, Leaf—A built-up spring made of flat stock like a carriage spring or locomotive driving spring.



Spring, Spiral—A spring wound with one coil over the other as in a clock spring. Usually of flat stock, but not always.



Spring, Tension—A helical spring which tends to lengthen in action.



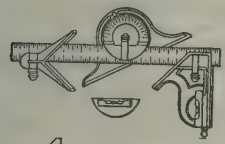
Spring, Torsion—A helical spring which operates with a coiling or uncoiling action as a door spring.



Spring, Valve—A helical spring used on valve stems and similar places; each coil being smaller than the one below, in order that the spring may close up into a very small space and then have a considerable range of action.

Sprue Cutter—A cutting punch for trimming sprues from soft metal castings.

Square, Caliper—A square with a caliper adjustment for laying out work.

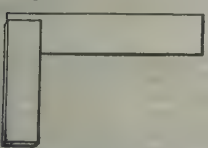


Square, Combination—A tool combining square, level and protractor in one tool.



Square, Center—For finding the center of a round bar by placing across the end and scribing lines in two different positions. Also used as a T-square. Not so much used as formerly.

T-square—A straight edge with a head at one end commonly used on the drawing board for drawing straight lines. It also forms a guide on which triangles are used.



Square, Try—Small square for testing work as to its being at right angles.

Steady Rest—A rest attached to the lathe ways for supporting long, slender work.

Steel, High-speed—A name given to steels which do not lose their hardness by being heated under high-speed cuts. Alloy steels which depend on tungsten, chromium, manganese, molybdenum, etc., for their hardness.

Stocks, Ratchet—Die stocks with ratchet handles.

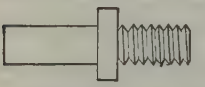
Straight Edge—A piece of metal having one edge ground and scraped flat and true. Small ones are sometimes made of steel but large, straight edges are usually of cast iron, proportioned to resist bending, and are used for testing the truth of flat surfaces such as plane ways.



Strapping—A method of buffing by the use of a flexible strap or belt, usually made of cloth and covered with abrasive held in place by glue. Runs over two pulleys or one pulley and a rod or plate, at high speed.

Stripper—A plate placed over the die, in a punch press, with a gap beneath to admit the sheet stock and an opening to allow the punch to pass freely; upon the up-stroke of the punch it prevents the strip of metal from lifting with the punch.

Stud, Collar—The collar stud forms a satisfactory device for carrying gears, cam rolls, rocker levers, etc. It is often provided with a hole at the end for a cutter pin or is slotted for a split washer, to retain the gear, or other part in place.

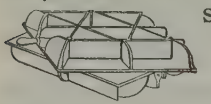


Stud, Shoulder—A stud of this form is used for mounting levers and other parts which could be operated on a plain, unthreaded stud, which stud, however, cannot be conveniently set or removed when necessary. It is also a form of post or guide sometimes employed in machine construction for carrying one or more sliding parts.

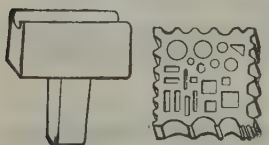


Stud, Threaded—See Bolts, Nuts and Screws.

Surface Plates—Cast-iron plates have surfaces scraped flat for use in testing work. Should be made in sets of three and so scraped that each one has a perfect bearing with the other two.

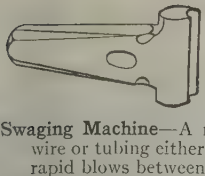


Swaging—Changing the sectional shape of a piece of metal by hammering, rolling or otherwise forcing the particles to change shape without cutting.



A *B*

Swaging Blocks—Blocks of cast iron or steel to assist blacksmith in swaging and bending iron to various shapes. *A* is for use in the hardy hole in the anvil, *B* can be used anywhere but is usually on or beside the anvil.



Swaging Hammer—A connection with the swaging block to swage metal to the desired size and shape.

Swaging Machine—A machine for reducing, tapering or pointing wire or tubing either between rolling dies or by hammering with rapid blows between dies of suitable shape.

Sweating—Another name for soldering.

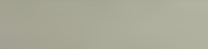
Swing of a Lathe—In the United States the swing of a lathe means the largest diameter of the work that can be swung over the ways or shears. In England it means the distance from lathe center to the ways or one-half the U. S. measurements.

T

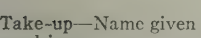
Take-up—Name given to device for taking up slack in belt or rope drives.

Tap—Hardened and tempered steel tool for cutting internal threads. Has a thread cut on it and flutes to give cutting edges.

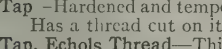
Tap, Echols Thread—This form of tap has every other thread cut away on each land, but these are staggered so that a space on one land has a tooth behind it on the next land. This is done for chip clearance.



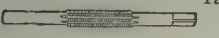
Tap, Hob, Sellers—Has threads in center and numerous flutes. For hobbing dies and chasers.



Tap, Patch-bolt—Tap for boiler makers' use in patching boilers. Sizes vary by sixteenths from $\frac{1}{2}$ inch to $1\frac{1}{4}$ inches. All threads are 12 to the inch and taper is $\frac{3}{4}$ inch per foot.

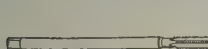


Tap, Pulley—Tap with a long shank to reach the hub of pulley for tapping set-screw holes.



Tap Remover—Device for removing broken taps. Usually have prongs which go down in the flutes and around the central portion.

Tap, Staybolt—Tap for threading boiler sheets for staybolts. *A* reams the hole, *B* is a taper thread, *C* is straight thread of right size, *D* square for driving tap. All standard staybolt taps have 12 threads per inch.



Tap, Step—Tap made with "steps" or varying diameters. Front end cuts part of thread, next step takes out more and so on to the end. Only used for heavy threads, usually square or Acme.

Tapped Face-plate—Having a number of tapped holes instead of slots. Studs screw in at any desired point.

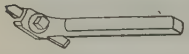
Tapping Machine—For cutting threads with taps (tapping) in nut or other holes.



Toggle—Arrangement of levers to multiply pressure obtained by making movement given to work very much less than movement of applied power.

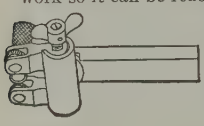
Tool, Diamond—Black diamond set in metal for truing emery or other abrasive wheels. Also used for cutting metal.

Tool Holder, Lathe or Planer—A body or shank, adopted to hold small pieces of tool steel for cutting tools. These can be removed for sharpening or renewal without moving the holder and saves resetting the tool to the work.



Tools, Inserted Cutter—Holders in which are held small steel cutting tools. These are usually removed for grinding or replacing when broken or worn out. Now made of high-speed steel.

Tool, Knurling—For roughing or checking the outside of turned work so it can be readily grasped by hand. The tool is a wheel with the desired markings cut in the edge and hardened. It is forced against the work and actually forces the metal up into the depressions in the wheel. Most knurls are held in the end of a hand tool but for heavy knurling they are made to go in the tool post as shown

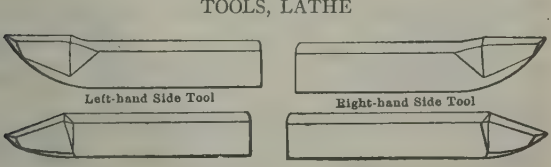


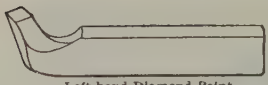
TOOLS, LATHE—WM. SELLERS & CO.

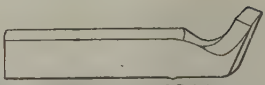
Lathe

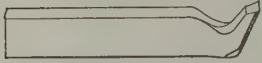
e Thread	60° V Thread	Bent Side	Side	Bent Roughing	Roughing	Kind of Tool
Right	Right	Right	Right			
Top d 0° Side b 10° Side a 10°	Top d 0° End c 15° Side b 7° Side a 12°	Top d 12° End c 6° Side a 6°	Top d 12° End c 6° Side a 6°	Top d 22° Side c 6° Side b Side a 6°	Top d 29° Side c 6° Side b Side a 6°	Face
						Clearance
e Thread	60° V Thread	Bent Side	Side	Nicking	Finishing	Kind of Tool
Left	Left	Left	Left			
Top d Side b 10° Side a 0°	Top d End c 12° Side b 12° Side a 7°	Top d 12° End c 6° Side a	Top d 12° End c 0° Side a 6°	Top d 1° End c 6° Side b 3° Side a 3°	Top d 13° End c 6° Side b 4° Side a 4°	Face
						Clearance
e Thread Bent	60° V Thread Bent	Inside Bent	Bent Brass	Bent Nicking	Bent Finishing	Kind of Tool
Right	Right	Left	Right	Left	Left	
Top d 0° Side b 10° Side a 14°	Top d 0° End c 36° Side b 7° Side a 14°	Top d 12° End c 6° Side a 3°	Top d 0° End c 10° Side b 6° Side a 10°	Top d 1° End c 6° Side b 3° Side a 3°	Top d 15° End c 6° Side b 4° Side a 4°	Face
						Clearance
e Thread Bent	60° V Thread Bent	Inside Bent	Brass	Bent Nicking	Bent Finishing	Kind of Tool
Left	Left	Right		Right	Right	
Top d Side b 10° Side a 0°	Top d 0° End c 15° Side b 12° Side a 7°	Top d 12° End c 6° Side a 6°	Top d 0° End c 10° Side b 6° Side a 10°	Top d 1° End c 6° Side b 3° Side a 3°	Top d 15° End c 6° Side b 4° Side a 4°	Face
						Clearance

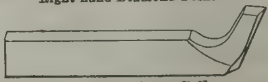
TOOLS, LATHE

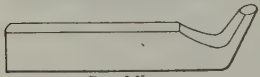


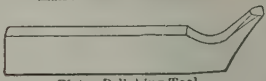

Left-hand Diamond Point

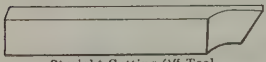

Right-hand Diamond Point

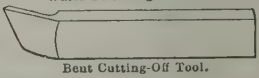

Bent Right-hand Diamond Point

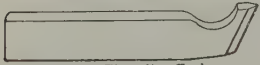

Half Diamond Point, R.H.

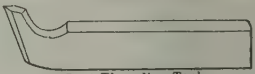

Round Nose.


Water Polishing Tool.

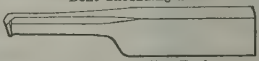

Straight Cutting-Off Tool.

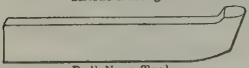

Bent Cutting-Off Tool.

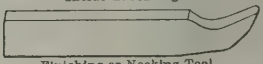

Straight Threading Tool.

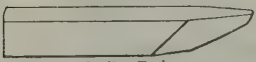

Bent Threading Tool.

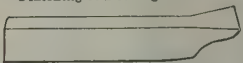

Inside Boring Tool.


Inside Threading Tool.

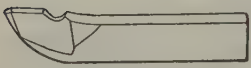

Bull Nose Tool.

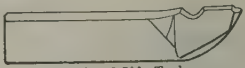

Finishing or Necking Tool.

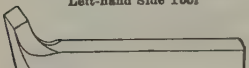

Scaling Tool.

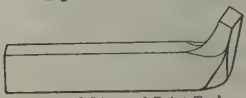

For Truing Up Centers, &c.

TOOLS, PLANER

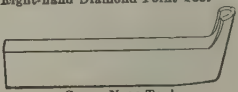

Left-hand Side Tool

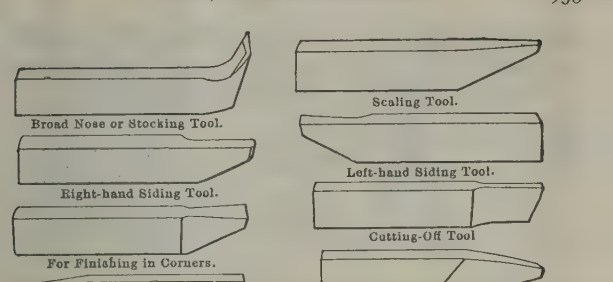

Right-hand Side Tool


Left-hand Diamond Point Tool.


Right-hand Diamond Point Tool


Bull Nose, for Heavy Cuts.


Gouge Nose Tool.



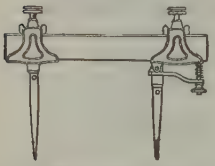
TOOLS, PLANER AND SLOTTER

lotter	Planer					
Corner	Chamfering	Bent Finishing	30° Angle	Side Finishing	Finishing	Kind of Tool
		90° Right	Right	Right		
End c 7° / Side b 4° / Side a 4°	Top d 0° / End c 4° / Side b 4° / Side a 4°	Top d 7° / End c 4° / Side b 4° / Side a 3°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 15° / End c 0° / Side b 4° / Side a 6°	Top d 7° / End c 4° / Side b 3° / Side a 3°	Face
	Top d 0° / End c 0° / Side b 8° / Side a 4°	Top d 7° / End c 7° / Side b 4° / Side a 3°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 15° / End c 0° / Side b 4° / Side a 6°	Top d 7° / End c 4° / Side b 3° / Side a 3°	Clearance
Square	45° Angle Slot	Bent Finishing	30° Angle	Side Finishing	Splining	Kind of Tool
	Right & Left	90° Left	Left	Left		
Side e 4° / Side d 4° / Side c 4° / Side b 4° / Side a 4°	Top d 0° / End c 4° / Side b 4° / Side a 3°	Top d 7° / End c 4° / Side b 4° / Side a 3°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 15° / End c 0° / Side b 4° / Side a 6°	Top d 3° / End c 4° / Side b 2° / Side a 2°	Face
	Top d 0° / End c 0° / Side b 8° / Side a 4°	Top d 7° / End c 7° / Side b 4° / Side a 3°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 15° / End c 0° / Side b 4° / Side a 6°	Top d 3° / End c 4° / Side b 2° / Side a 2°	Clearance
Splining	30° Angle Slot	45° Angle	40° Angle	Bent Side Finishing 45°	Cutting Down	Kind of Tool
	Left	Left	Left	Left	Left	
End c 3° / Side b 4° / Side a 4°	Top d 0° / End c 4° / Side b 4° / Side a 4°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 15° / End c 0° / Side b 4° / Side a 6°	Top d 0° / End c 4° / Side a 6°	Face
	Top d 0° / End c 0° / Side b 8° / Side a 4°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 15° / End c 0° / Side b 4° / Side a 6°	Top d 0° / End c 4° / Side a 6°	Clearance
Hexagon	30° Angle Slot	45° Angle	40° Angle	Bent Side Finishing 45°	Cutting Down	Kind of Tool
	Right	Right	Right	Right	Right	
Side c 4° / Side b 4° / Side a 4°	Top d 0° / End c 4° / Side b 4° / Side a 4°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 15° / End c 0° / Side b 4° / Side a 6°	Top d 0° / End c 4° / Side a 6°	Face
Side d 4° / Side c 4° / Side b 4° / Side a 4°	Top d 0° / End c 0° / Side b 8° / Side a 4°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 0° / End c 4° / Side b 4° / Side a 6°	Top d 15° / End c 0° / Side b 4° / Side a 6°	Top d 0° / End c 4° / Side a 6°	Clearance

r Wrenches

Tote Boxes or Pans—Pans or trays, usually of steel, for carrying or storing small parts.

Train—A series of gears, as the feed train of a lathe connecting spindle with lead screw. Also applied to series of levers.

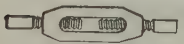


Trammels—For drawing large arcs or circles or for laying out center distances. Frequently called "trams." Fit on a beam and their capacity depends on the length of the beam.

Trepanning Tool—Tool for cutting an annular groove outside or around a bored hole.

Tripper—Device that trips any piece of mechanism at the desired time. An example is found in conveyers where the tripper dumps the material at the desired point.

Tumbler Gear—An intermediate gear which meshes in between other gears to reverse the direction of the driven gear of the train.



Stub End



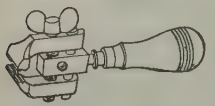
Hook and Eye

Turn Buckle—Really an elongated nut for connecting and tightening truss rods, tie rods, etc., used in construction work. Some have right- and left-hand threads as at top. Others thread in one end only.

Tuyere—The pipe or opening into forge through which air is forced.

V

Vise, Drill—Vise for use on drill press to hold work being drilled.



Vise, Hand—A small vise to be held in the hand. For small work that requires turning frequently to get at different sides.

Vise, Jig—A drill vise with arms which carry bushings so that pieces can be drilled in duplicate without special jigs for them.

Vise, Pin—Small hand vise for holding small wire rods.

V's—Ways shaped like a V, either raised above the bed as on a lathe or cut below as in a planer, for guiding the travel of a carriage or table.

W

Washer, Open—Washers with one side open so as to be removed or slipped under the nut to avoid necessity of taking the nut entirely off. Also called a "C" washer.

Watt—The unit of electrical power and equals volts multiplied by amperes. 746 watts are equal to 1 horsepower.

Ways—The guiding or bearing surfaces on which moving parts slide, as in a lathe plane or milling machine. The ways may be of any form, flat, V or any other shape.

Welding—The joining of metals by heating the parts to be joined to the fusing point. Welding in an open fire is usually confined to iron and steel but nearly all metals can be joined by electric or oxyacetylene welding.

Wind—Pronounced with a long *i* as in "mind" and refers to a twist or warping away from straightness and parallelism.

Wrench, Bridge Builders'—Large heavy wrench with a hole in end for a tackle to apply power.

WRENCHES, MACHINE

A variety of wrenches are illustrated herewith, and the usual name given.

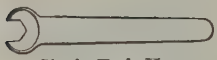
A 15-degree angle opening permits the turning of a hexagon nut completely around where the swing of the handle is limited to 30 degrees.

A $22\frac{1}{2}$-degree angle opening permits the turning of any square head bolt or screw completely around where the swing of the handle is limited to 45 degrees.

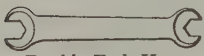
Unfinished drop-forged wrenches are plain forgings, with openings milled to fit the nut or screw on which they are to be used.

Semifinished wrenches are milled to fit the nut or screw on which they are to be used and case hardened all over.

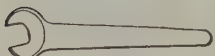
Finished wrenches are milled to fit the nut or screw on which they are to be used and are ground, polished, case hardened all over, lacquered, with heads bright.



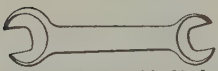
Single End, Hex.



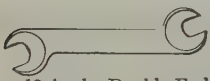
Double End, Hex.



15° Angle, Single End



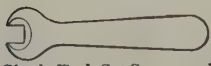
15° Angle, Double End



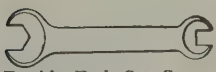
22½° Angle, Double End



S — 22½° Angle



Single End, Set Screw and Machine



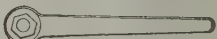
Double End, Set Screw and Machine



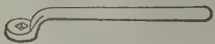
"Box"-Tool Post



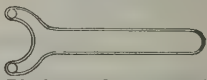
Double End, Tool Post



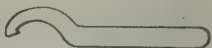
Hex. Box, 15° Angle



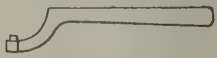
Chuck



Pin-face, For Round Nuts Having Holes in their Face to Receive the two Wrench Pins



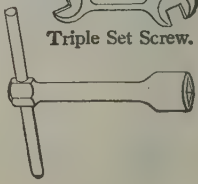
Hook Spanner, Milled out to suit Round Nuts Having Notches in the Periphery to Receive the Hook at the End of Spanner



Pin Spanner Used on Round Nuts which have Holes in the Periphery to receive the Spanner Pin



Triple Set Screw.

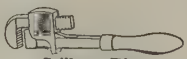


Socket

WRENCHES, MISCELLANEOUS



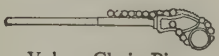
Monkey or Screw



Stillson Pipe



Pocket Adjustable



Vulcan Chain Pipe



General Utility



Pipe Tong



Construction



Track



Wrench, Tap—Wrench for holding and turning taps. Usually made adjustable for different sizes.

Wringing Fits—See Calipering and Fitting.

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